LECTURES
IN
Experimental Philoſophy.

BY

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Mr. L'ABBE NOLLET, k

Member of the Royal Academy of Sciences at PARIS,

AND

Fellow of the Royal Society at LONDON.

Tranſlated from the French

By *JOHN COLSON*, A. M. F. R. S.

And Profeſſor of Mathematicks in the Univerſity of
CAMBRIDGE.

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TO

Monſeigneur the DAUPHIN.

MONSEIGNEUR,

AFTER I had formed a Deſign of writing and publiſhing a Courſe of Lectures in Experimental Philoſophy, which I had taught for many years; I could not have wiſhed a more favourable Opportunity, to offer them to the Publick, than ſince you have been pleaſed to honour them with your Preſence and Regard. I ſhall now be excuſed, in the Publication of this Work, from extolling the Uſefulneſs of it's Subject, or ſhewing the Dignity of it: For theſe are ſufficiently proved, by becoming the Subject of your Inquiries, and by having the Approbation of thoſe wiſe Counſels which conduct your Studies. Such an Example would fully inſtruct us, were it not already univerſally acknowledged, that the Knowledge of natural Effects is ſuitable to all Conditions. We might alſo conclude from it, that it is ſuitable to all Ages; had you made no more than a common Proficience in other Sciences, and had we not known the Proofs you have given, of a Genius already arrived at a State of Maturity.

For theſe Ten Years that I have endeavoured to form, and bring to Perfection, a School of Natural Philoſophy, what has moſt animated and ſupported my Zeal in this laborious Undertaking, was the Hope I flattered myſelf with, of being able one Day, Monſeigneur, to offer the Fruits of it to you. That Day is now come, the Limit of my Hopes and Deſires, and your own Commands engage me to it.

The Publick will be informed of my good Fortune by this Dedication, and without doubt will perceive with Pleaſure, that in making uſe of my weak Abilities, you honour with your favourable Regards an Inſtitution, to which it has already given it's Approbation. And everybody will be convinced, as well as myſelf, how happy I am to have ſo favourable an Occaſion of profeſſing my Zeal, and of giving this publick Teſtimony of my inviolable Attachment, and of the profound Reſpect, with which I ought to be, and always ſhall be,

MONSEIGNEUR,

Your moſt Humble,

moſt Obedient, and

moſt Faithful Servant,

J. A. NOLLET.

PREFACE.

WHEN a Science comprehends only ſome Queſtions of ſmall Conſideration, or tho' they may ſeem to be of ſome Importance, yet if it determines thoſe Queſtions only by probable Arguments, and is ſupported only by ſpecious Hypotheſes; ſuch a Science will engage the Attention of but few. It ſeldom comes into much Credit, nor will it receive any Improvement from Time, unleſs the Object of it be enlarged and reformed. For the Deſire of Knowledge, which is innate in us, and which alone can excite our Application, will naturally lead us to the Love of Truth, and will fix us therein, when we have any Intereſt to ſerve by it.

THIS Reflection may eaſily be confirmed by the Hiſtory of Natural Philoſophy, if we do but conſider the ſeveral Revolutions it has ſuffered from Time to Time.

For near Twenty Ages this Science has hardly been any thing elſe, than a Collection of empty Syſtems, heaped one upon another, and often contradictory to one another. Every Philoſopher thought himſelf at Liberty to raiſe a kind of Monument to his own Reputation, which was built upon the Ruins of all that went before him. Nothing could be perceived but ſome plauſible Scheme, which deſtroyed an Hundred others which ſeemed as plauſible.

These vain Attempts, ſo often renewed, gave but little Credit to the Opinions of Philoſophers: And the Effect naturally reſulting from thence, was to keep Men in Suſpence about the Doctrine of all Natural Philoſophers. Nor can we be much ſurprized, if their Curioſity was but little moved by a kind of Knowledge, in which they ſaw ſo much Uncertainty to prevail, eſpecially when delivered in Terms which were ſo obſcure. For in thoſe Ages of Barbarity, as if the Sciences were aſhamed of their own Nakedneſs, and did not care to be too openly expoſed, thoſe that profeſſed them affected a Language which conveyed none but confuſed Ideas, the greateſt part of which were abſolutely unintelligible, except to thoſe who had before reſolved to be ſatisfied with them. Inſtead of Explanations they had recourſe to

Words void of Meaning, which had been introduced by the Authority of ſome great Names, and which a too awful reſpect ſtill obliged them to retain, tho' they could not derive any Light from them.

But tho' Natural Philoſophy had hitherto been cultivated very imperfectly, and was hardly known, yet at laſt ſhe appeared in open Day, and was received with Approbation when ſhe offered uſeful Diſcoveries, and evident Truths, and when ſhe became intelligible to all the knowing World. *Des Cartes* was her firſt Reformer, and drew her out of the Obſcurity of the Schools, where ſhe had grown old under the Authority of *Ariſtotle*. He left her nothing but the Name ſhe had hitherto been known by, and made her ſuch as the Schools themſelves, after being reformed themſelves by degrees, have adopted her in this new State, and teach her now in Terms that are intelligible.

This Reformation conſiſts chiefly in the Manner of ſtudying Nature. Inſtead of making Conjectures, as had been the Practice before, and giving her as many Intentions and particular Powers as were the Phænomena to be explained, they took the Courſe of examining her by Experiment, of penetrating into her Myſteries by diligent and well directed Obſervations, and made

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When the Taſte for Phyſicks became almoſt general, it was then expedient to have it's Principles digeſted in ſuch a manner, that every body might reap the Benefit of them. We ſoon ſaw then Elementary Treatiſes in ſeveral Languages, which in this reſpect might ſupply the Wants of the Publick. But the Science they treated of grew under their Hands, and advanced more and more towards Perfection. Diſcoveries increaſed, Errors were corrected, and Doubts were cleared up. The ſame Motives that cauſed them to compoſe theſe Elements, obliged them to renew them from Time to Time, in order to admit the Improvements, the Corrections, and the Illuſtrations, which were of great Uſe to ſuch as were concerned in the Progreſs of this Science. Beſides it was neceſſary that this Kind of Works ſhould be adapted to the Genius and Capacity of the ſeveral Readers for whom they were deſigned. I know many excellent ones of this Sort, which have ſucceeded well in England, in Holland, in Germany, and which, if they were tranſlated into our Language, would hardly meet with ſo many Readers in France, becauſe the Principles are delivered in too cloſe and conciſe a manner, and require too ſtrict Attention for thoſe who would only amuſe themſelves uſefully; and becauſe they contain more Geometry than is generally known by moſt People.

'Tis now about five Years ſince I publiſhed the Plan of my intended Courſe of Experimental Philoſophy, in which I gave an Account of my Manner of forming this Undertaking, and of the Progreſs it had made ſince it's Commencement. I then offered this ſmall Piece to the Publick, as a Table of Contents (*a*), which I propoſed to enlarge into a more conſiderable Work, and then lay it before the Publick, if it continued to favour my Endeavours, and if I had Reaſon to hope my Lectures would be agreeable. This has already ſucceeded even beyond my Expectation. When I propoſed this as a Condition, it was indeed a Motive to me, and at the ſame time a Limit that I fixed to my Zeal, for I only looked round about me, and did not extend my Views beyond

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(*a*) Plan, or general Idea of a Courſe of Phyſicks, Pref. p. 33.

the Bounds of Paris. I little imagined that my weak Talents would be known beyond the Alps (*b*), and that I ſhould have the Honour of exerciſing them in a foreign Court. I could not preſume that my School ſhould not only be applauded, but alſo made a Pattern for the Colleges in our diſtant Provinces (*c*), for Univerſities, and for Academies themſelves. Laſtly, I could not preſume to hope, that even our Princes *(d)* would honour my Courſes with

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(*b*) In 1739 I was called to the Court of Turin, where I continued near ſix Months, to read Leſſons in Natural Philoſophy to his Royal Highneſs the Duke of Savoy. After which the King ordered all the Inſtruments I had carried with me, to be laid up in the Univerſity, that the Profeſſors might make uſe of them afterwards, to improve and teach Phyſicks by the Method of Experiment.

(*c*) Since the Publication of my Plan, ſeveral Colleges, as that of the Oratory, of Chriſtian Doctrine, and of St Lazarus, have undertaken to introduce Experimental Proofs into their publick Exerciſes.

The Univerſity of Rheims does the ſame, and I have ſent them a Collection of Inſtruments, which is already very conſiderable.

The Royal Academy of Sciences, and of the Belles Lettres at Bourdeaux, have alſo furniſhed lately a fine Cloſet of Machines and Philoſophical Inſtruments, the execution of which they did me the honour to commit to my Care.

(d) In 1738 the Duke of Penthievre deſired to ſee one of my Courſes of Phyſick, at which his Serene Highneſs attended with great Application; and ſoon after I had the Honour to exhibit one at Verſailles, for his Serene Highneſs the Duke of Chartres, at the cloſing of his Studies.

their Preſence and Attendance, and that they would join their Approbation to that of the Publick: Nor that the Specimen they had of my Way of teaching, would procure me the Honour of performing in the Preſence, and for the Uſe, of Monſeigneur the Dauphin. This latter Advantage indeed was a Spur to my Zeal, but was what I may be ſaid rather to have wiſhed for than to have had the Courage to expect.

THESE glorious Events (which I here mention not out of Vanity tho' a ſufficient occaſion for it) are a kind of Pledge of the Succeſs of my Undertaking, and of the Approbation it may expect to meet with. It was on this Condition that I promiſed to publiſh this Work, of which Promiſe I now acquit myſelf. I ſhall make no Excuſe for having delayed the Publication for five Years. If I have any Reproach to fear, 'tis for putting it in the Preſs ſo ſoon. For if it is ſuch, as I could wiſh it to be, thoſe for whom it is deſigned will not take it amiſs, that I have taken all the Time that was neceſſary to render it worthy of them.

THE Title of the Work ſufficiently declares what it is. They are my Lectures, ſuch as I have uſed to read for theſe nine Years, to Companies aſſembled together to hear them in common. I always ſuppoſe that the greateſt Part of them are not prepared to underſtand Expreſſions of Algebra or Geometry, and abſtract Diſcourſes which recede too far from the firſt Principles. I conſider alſo, that the Uſe which might be expected, would be loſt to thoſe who are but beginning, or who intend to allow to this Study only ſome Moments of Recreation, and which ſhall not intrench upon their more neceſſary Occupations, whether in regard to their Buſineſs or Pleaſure. Wherefore being more taken up with the Care of being well underſtood, than with the Objection that might be made to me of forſaking the Language of the Sciences, which is ſo much affected by many; I endeavour to ſpeak and write, as many good Authors have done before me, whoſe Works are accommodated to general Uſe.

'TIS not that I have any Diſlike to theſe Forms of Expreſſion, or to the uſual Terms of Art, which are certainly more preciſe, and more contracted, and which put it in our Power to purſue further a great many of theſe Speculations, which are the Subject of my Lectures; for I make Uſe of them myſelf to good Advantage, when I aſſiſt in a private way, ſuch Perſons as are deſirous to make Phyſicks a more ſerious Study, and who are prepared for it by a good Proficience in Mathematicks. But having Regard to the greateſt Part of my Readers, I have not thought proper to introduce into my Work, ſuch Calculations and Deductions which may be diſpenſed with, and which would require more Pains and Application than can be expected from them. I have rather choſe to reſerve them for ſeparate Volumes, which I may give hereafter by way of Supplement, and under the Title of Annotations.

Tho' I have avoided the Uſe of any Algebraick Expreſſion, or any Geometrical Symbol, for the ſake of Readers to whom this Language may not be very familiar; yet I have not carried this Reſtraint ſo far as to forbear the Uſe of ſuch Terms as Cuſtom has appropriated to theſe Matters. I have adopted the uſual way of Expreſſion, that the reading of my Work may ſerve as an Introduction to other Books of Phyſicks. But I have took Care to diſtinguiſh theſe Words by the Italian Character, when firſt they are made Uſe of, and to define and explain them in the cleareſt Manner poſſible. And not to interrupt the Diſcourſe by too frequent Definitions, which would be uſeleſs to many Perſons, I have placed a little

Vocabulary before this firſt Volume, and a Plate in which Beginners may find an Explanation of ſuch Terms as will occur frequently in the Body of the Work, and which I ſhall ſuppoſe to be known by moſt of my Readers.

I do not liſt myſelf here under the Standard of any of the celebrated Philoſophers. 'Tis not the Phyſicks of *Des Cartes*, nor of *Newton*, nor of *Leibniz*, that I propoſe particularly to follow; but without any perſonal Preference, and without Diſtinction of Names, 'tis that which, by the general Vogue, and by well atteſted Facts, ſhall appear to me to be beſt eſtabliſhed. I have all the Reſpect and all the Acknowledgment poſſible for thoſe great Men, who have imparted their Thoughts to us, and have enriched us with their Diſcoveries, in whatever Time and whatever Nation they have lived. I admire their Ingenuity, which is conſpicuous even in their Errors, and think it my Duty to pay them the Honours due to them. But I take nothing upon their bare Word, except what I find to be confirmed by Experience. In Matters of Natural Philoſophy, we muſt not pay an abſolute Submiſſion to the greateſt Authority; much leſs ought we to be Slaves to our own Prejudices, but to embrace the Truth wherever we find it, and not affect to be

Newtonians at *Paris*, or *Carteſians* at *London.*

To confine myſelf the more ſtrictly within the Limits of my Title, I have omitted to produce the different Syſtems which have been propoſed concerning the Mechaniſm of the Univerſe, which have divided the Philoſophers both antient and modern. Tho' indeed without much Harm one might be intirely ignorant of all theſe Sallies of Imagination, which for the moſt part are not much to the Honour of the human Mind, and of which the very beſt is nothing elſe but an ingenious *may-be*; yet we can hardly be diſpenſed with from knowing thoſe which have gained the greateſt Reputation; and I ſhould willingly mention what *Des Cartes* and *Newton* have delivered on this Subject, were I not prevented by an Author whoſe Work (*e*) is in every one's Hands, and who has treated on this Matter with the ſame Delicacy, as is to be found in all his other Writings.

I HAVE ſtudiouſly ſhunned all metaphyſical Diſquiſitions, that might ſeem to ariſe from my Subject, that I might not recede from ſenſible Phyſicks, and ſuch as are to be ſupported by Facts. They that would ſupply this ſeem-

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(*e*) The Hiſtory of the Heavens, B. II.

ing Defect, which I have fallen into by Deſign, may receive much Satisfaction by reading the Works of Father *Malebranche*, and particularly that which he calls *A Search after Truth*.

In penning my Lectures I have obſerved the ſame Method that I have been uſed to follow, when I delivered them *viva voce*. In each Matter I have choſe what I thought moſt intereſting, what is the neweſt, and which might be beſt proved by Experiments. I explain the State of the Queſtion with all the Exactneſs and Clearneſs I am able; I ſearch into it's Original, and take Notice of ſuch Authors who ſeem to have handled it with moſt Succeſs. Then I prove it by Operations of which I ſhew the Mechaniſm, taking Care to ſeparate it from whatever is foreign to the Purpoſe, that the Attention may not be diverted. Laſtly, I bring together whatever has Relation to the Queſtion itſelf, or to the Facts which I bring as Proofs; and that either in the Phænomena of Nature, or in the Proceſſes of the Arts, or in the Machines that are moſt in uſe for the Conveniencies of Civil Life. Thus I have always proceeded from the firſt opening of my Courſes; and after having carefully ſtudied the Taſte of the People in this reſpect, I have met with nothing to prevail with me to change this Order, but am rather perſuaded, that it has had all the Succeſs

I could propoſe to myſelf. I have always been convinced, that Principles which are often abſtracted enough, and which cannot be learned ſucceſſively without a painful Application, may yet be eaſily inſinuated into the Mind, when they are thus interrupted by engaging Experiments, which at the ſame time oblige us to acknowledge their Uſefulneſs and Truth.

In the Diſtribution of the Matter, which ought to be conſidered as the principal Part of this Work, I have endeavoured to collect, under the ſame Title, ſuch things as have a neceſſary Connexion with one another; and I have taken Care to place thoſe Propoſitions firſt which are more eaſily underſtood, and which are to ſerve as Principles for the underſtanding thoſe that follow. Thus in Strictneſs, tho' one may take every Lecture ſeparately, and tho' they have generally a kind of Independence on one another; yet I ſhould always adviſe the Reader, if he would peruſe them with more Eaſe and Advantage, to take them in the Order they ſtand here, becauſe he will find ſuch Notions in the former, which will aſſiſt him to underſtand the latter.

The Facts I make uſe of to prove my Propoſitions, are not always ſo many, or ſo new as they might have been. Thoſe that have ſeen my Apparatus of Inſtruments, and have been preſent at my Courſes, will wonder perhaps that in the Plates belonging to this Work, they only find a Part of what they have ſeen in my Collection: It is fit I ſhould give a Reaſon why I ſuppreſs what perhaps they might deſire to ſee, if I propoſe theſe Volumes as a compleat Collection of my Demonſtrations.

Ever ſince I undertook to teach Experimental Philoſophy I have been convinced, that the ſureſt Method of gaining Attention, and of readily exciting the neceſſary Ideas, was according to the Obſervation of a famous Poet (*a*), to ſpeak to the Eyes by ſenſible Repreſentations. In Compliance with this Truth, I provided myſelf with certain Machines I had contrived, to make my Thoughts be underſtood by thoſe who have but a ſlight Acquaintance with the Sciences, and to make them comprehend eaſily and very ſoon ſome Notions, without which they would not readily enter into the State of the Queſtion, or apprehend the Proofs which eſtabliſh the Theory. But as theſe Methods are of no Significancy but in the Application, and the Pieces that compoſe them expreſs nothing but when they are in uſe, it would be needleſs to give a Deſcription of

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(*a*) Segnius irritant animos demiſſa per aures,
Quam quæ ſunt oculis ſubjecta fidelibus.
Hor. de Art. Poet.

them. It would be only to multiply Plates without Neceſſity, which already are but too numerous.

ANOTHER Reaſon why I have not repreſented in this Work all that may be ſeen in my School, is this. I was unwilling to introduce more Experiments, than what were ſufficient fully to prove the Doctrine they contain. I have already ſaid elſewhere (*a*), I never intended to make my Lectures a Shew for pure Amuſement, where one might ſee exhibited, without Deſign and without Choice, a great Number of Experiments fit only to engage the Eyes. I think myſelf more able than any one in France, to ſatisfy the Curious by the Choice and Variety of Machines with which I am provided, but I ſhould not be much pleaſed if any one came to me only to ſee them in Operation; for I always hope to find a more reaſonable Curioſity in my Audience. Therefore of all the Facts that I am able to produce to prove a Propoſition, I make uſe only of a certain Number which is ſufficient; and by this Management I gain Time for more neceſſary things, and I have an Opportunity of varying my Proofs uſefully and agreeably, for thoſe that attend my Courſes ſeveral Times. I have had the ſame View in

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(*a*) The Plan or general Idea of a Courſe of Natural Philoſophy; Pref. p. 10.

writing. I did not deſign to overwhelm the Reader with a ſuperfluous Number of Operations, ſo as to make him loſe Sight of the Doctrine to be eſtabliſh'd; but in producing Facts that are worthy of his Attention, I have ſet before him ſuch Proofs as may confirm the Knowledge he has already acquired. In a Word, whether at the firſt opening of my School to the Publick, or in producing my written Lectures, I had always this in View, that it might have not ſo much a Courſe of Experiments, as a Courſe of Experimental Philoſophy.

By the Deſcription I have given of my Inſtruments, under the Title of *Preparation*, I do not undertake to deſcribe them ſufficiently for any one to imitate their Conſtruction; for this would have required a long Proceſs of Propoſitions, of the Choice of Matter, of Precautions to be taken, and very often Particulars foreign to my main Deſign; which muſt have conſiderably enlarged the Bulk of my Work, to the Loſs of a great many Readers, who are ſatisfied to know in general, that ſuch a Machine will produce ſuch an Effect. Yet as I am ſenſible how uſeful it is, to have good Inſtructions concerning the Choice of Philoſophical Inſtruments, and concerning the Manner of conſtructing them; to comply with the Deſires of thoſe who apply themſelves to this Science, the Number of which increaſes every Day, I have reſolved to collect into a ſeparate Work, whatever a long Experience has inform'd me of theſe Matters. This Deſign is actually in Execution, and ſome Specimens of it may be ſeen in the Memoirs of the Academy of Sciences for the Years 1740 and 1741, where I have only omitted what chiefly concerns the Workman.

As to my Choice of Experiments, I have ſometimes preferr'd thoſe which have been long known, before others that are more recent; either becauſe I found in them a more direct relation to the Propoſitions I had to prove, or becauſe they gave an Opportunity for Applications of more Importance, or laſtly becauſe they ſeem'd to me too neat to be omitted. Their Date then ſeem'd to me a Circumſtance of no Weight, for as this Work is not compoſed for profeſt Artiſts, thoſe that ſee them here will ſtill find all the Recommendations of Novelty; and beſides, things may have other Merit as well as that of being new.

Perhaps I may be cenſured for admitting into my Applications ſome Remarks of ſmall Uſe, either becauſe the Subject does not deſerve the Pains, or becauſe they are obvious enough of themſelves. But it ought to be conſidered, that this Work is not made for ſuch Perſons only as have lived a good while in the World, and to whom a long uſe has convey'd ſome Ideas, though perhaps obſcure and confuſed enough, but by the Help of which they can perceive the near Cauſes of theſe common Effects; But I chiefly intend it for young Perſons of both Sexes, who paſs the firſt Years of their Lives in Colleges or Boarding-ſchools, to whom every thing is new in Nature, whoſe Minds are naturally inquiſitive after this kind of Knowledge, and who ought to be initiated in clear and diſtinct Ideas, and to judicious Inductions, by eaſy and familiar Examples. For it is the Obſervation of a learned Man, deſervedly in much Eſteem (*a*), That it is always requiſite to think juſtly, even in Matters of but ſmall Importance.

Besides, Care muſt be taken not to confound the Effect with it's Cauſe. That may be known by the moſt illiterate Peaſant, but the other not by the wiſeſt Philoſopher. Who does not know that a Spunge, a ſoft Stone, a Lump of Sugar, will be quite wet before it is wholly plunged into Water? But does every one know why this comes to paſs? Beſides, the moſt common Phænomena do not always appear to be ſo, when conſider'd in all their Circumſtances. Every one knows that a Stone

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(*a*) Mr de Fontenelle, Hiſtory of the Royal Academy of Sciences, for Anno 1600. Pref. p. 11.

falls in Conſequence of it's Weight; but every one does not know, that in falling it deſcribes Spaces which anſwer to the Squares of the Times from the Beginning of it's Fall. After having proved this laſt Effect, if I ſhould make an Application of it, and ſay, that a Bottle or Glaſs might break by falling, I ſhould certainly inſtruct no body. If I ſhould ſay beſides, that the higher their Fall is, the greater Riſque they would run of being broken, this Truth would appear no newer than the former. But if I ſhould add, that by falling a heavy Body is broken in Conſequence of it's accelerated Velocity, and that one might foreſee the Effort it is able to make at the End of it's Fall, by meaſuring the Height of the Place from whence it falls; I cannot think this Obſervation would be uſeleſs to all thoſe to whom I propoſe it. And if after reading it any one ſhould complain, that I only inform him that a Glaſs may be broke by a Fall, or that the higher it falls, the more ſurely it will be broken; he would either ſhew but little Penetration, or much Perverſeneſs.

THANKS to the good Taſte which prevails in this Age, I can eaſily be diſpenſed with from ſhewing, that Natural Philoſophy is uſeful, and that there is Nobody but what may have ſome Advantage from the Improvements that are made every Day. Though this Science bears a Greek Name, 'tis now well known, that it's Object is no Foreigner. That the Knowledge it offers is uſeful to every Body, and that what it proclaims by the Voice of Experiment, may be heard by every Age, and in all Places. The Study of Nature was yet, as one may ſay, in it's Cradle; the Knowledge that was acquired of it's Phenomena and their Cauſes hardly deſerved the Name of Science, when one of the greateſt Men of Antiquity (*a*) thus cried her up, as the greateſt Solace of the Mind of Man, as an Employment from whence it might derive Advantage at all Times, and in all Circumſtances of Life. With how much more Reaſon may it now be recommended as ſuch, when it engages whole Societies of learned Men in all civilized Countries, that Princes honour it with their Protection, and ſupport it by their Liberality? I ſay at this Time, when it's Advancement is proclaim'd every Year by whole Volumes, from which every one may derive, either according to his Inclinations or Occaſions, ſuch Instructions as will at leaſt improve and adorn his Mind.

(*a*) Hæc ſtudia adoleſcentiam alunt, ſenectutem oblectant; ſecundas res ornant, adverſis perfugium ac ſolatium præbent; delectant domi, non impediunt foris; pernoctant nobiſcum, peregrinatur, ruſticantur. CICERO *pro Archiâ Poetâ*. No. 16.

In whatever Condition a Man is placed in the World, it ſeldom happens but he muſt ſometimes reflect on the Force of Bodies moving by their own Weight, or otherwiſe; upon that of Animals, upon the Impulſe and Motion of Fluids, upon the Action and Effects of a great Number of Machines, either old or new, on the Choice of which one has often occaſion to know how to determine properly. Is it poſſible to obſerve the wonderful Effects of Teleſcopes, Optick-glaſſes, and Microſcopes, the uſe of which is now become ſo common, without wanting to know the Mechaniſm and Properties on which the Conſtruction of theſe Inſtruments depends? To whom can it be of no uſe to be inform'd of what is new in a Science, which adminiſters to our moſt rational Amuſements, our Conveniencies, or Neceſſities? Can it be a Matter of Indifference to us, whether we know or not ſuch things, as can employ us at leaſt agreeably, at ſuch Times and in ſuch Places as we cannot enjoy the Pleaſures of Society?

But the higheſt Advantage, and that which every generous Mind cannot but be ſenſible of in ſtudying Nature, is the Neceſſity it lays us under of acknowledging every where the ſupreme Being, who has form'd this immenſe Univerſe, and who continually ſuperintends by his

Providence over theſe his own Works. The farther we proceed in this Study, the more we ſhall be convinced, that the Object of it is not the Production of Chance. Every thing in it declares an infinite Power which amazes, a profound Wiſdom which is aſtoniſhing, Deſign and Goodneſs which demand all our Acknowledgment. Theſe Wonders which we have before our Eyes, ſpeak to the Heart as well as to the Underſtanding: In inſtructing the one, it will naturally touch the other. What we learn of them, as it makes us leſs ignorant than the Vulgar, ſo it gives us more lively Sentiments of our Duty, and makes us more diligent to perform it.

An illuſtrious Prelate (*a*), in giving an Account of the Education of a great Prince, which had been entruſted to him, furniſhes me with an Example, and alſo an authentick Proof, of the good Effects which may be hoped from Natural Philoſophy, when the Principles of this Science are taught with Choice and Deſign, and the Perſon inſtructed in it is capable of Reflection. I ſhall conclude my Preface with a Tranſlation of his own Words, as they are found in that Work of his, which bears the Title of

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(*a*) Mr Boſſuet, Biſhop of Meaux, in his Latin Letter to Pope Innocent XI. concerning the Education of the late Dauphin, p. 16.

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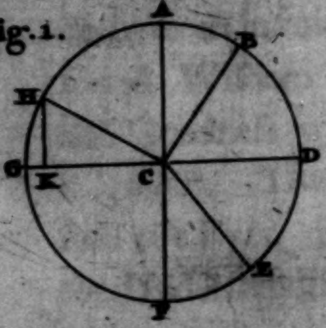
Fig. 1.



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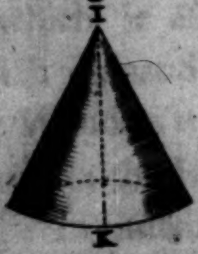

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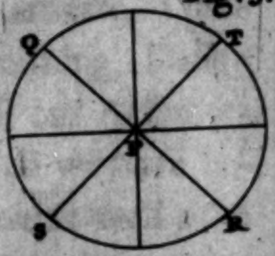

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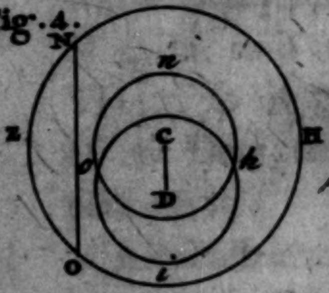

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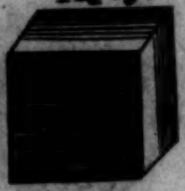

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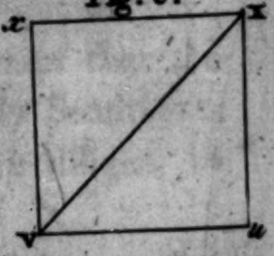

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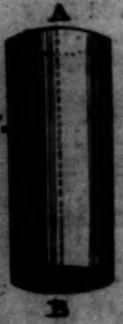

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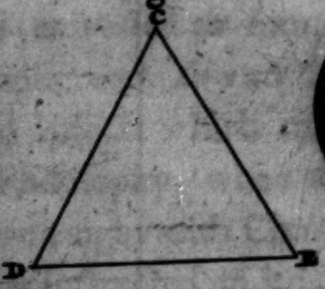
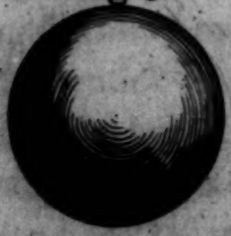


Fig. 9



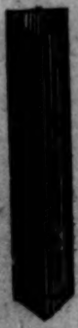


Fig. 12.

Fig. 10.

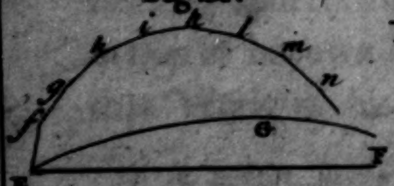
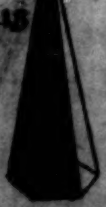


Fig. 13



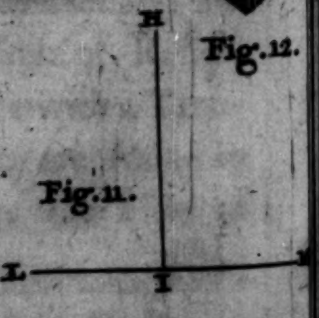


Fig. 11.

W. H. Toms ſ

Politicks extracted from the Holy Scriptures, p. 41 *(a).*

As to Experiments of natural things, ſays he, we have took Care that the moſt uſeful and the moſt elegant ſhould be perform'd before the Prince; in which he has not found leſs Profit than Entertainment. They have made him acquainted with the Induſtry of the human Mind, and the nobleſt Inventions of the Arts; whether to diſcover the Secrets of Nature, or to adorn her, or to give her Aſſiſtance. But what was the moſt conſiderable, He has there been acquainted with the Art of Nature herſelf, or more truly with the Providence of God, which is at the ſame Time ſo manifeſt, and yet ſo conceal'd.

(a) Experimenta verò rerum naturalium ſic exhiberi fecimus, ut in his Princeps ludo ſuaviſſimo atque utiliſſimo, humanæ mentis hiſtoriam, præclaraque artium inventa, quibus naturam & retegerent & ornarent, interdum adjuvarent: ipſam denique naturæ artem, immò ſummi Opificis & potentiſſimam & occultiſſimam providentiam miraretur. BOSSUET, *loc. citat.*

A TABLE

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Exper. I. *In which equal Maſſes are uſed.*

Exper. II. *In which the Body ſtruck has twice as much Maſs at the ſtriking Body.*

Exper. III. *In which the ſtriking Body has twice as much Maſs as the Body ſtruck.*

Propoſition II. *When two Bodies ſtrike one another, which move the ſame way with unequal Velocities, whether their Maſſes be equal or not, they will continue to move together in their firſt Direction, with a common Velocity not ſo great as that of the ſtriking Body, but greater than that of the Body ſtruck before the Percuſſion.*

Exper. I. *With equal Maſſes, the Velocities being in the Ratio of 1 to 2.*

Exper. II. *With Maſſes that are double one to the other, and with Velocities which are reciprocally as the Maſſes.*

Exper. III. *In which one of the two Bodies has but half the Maſs of the other, but has double it's Velocity.*

Propoſition III. *If the two ſtriking Bodies move directly contrary to each other, the Motion in both will be deſtroy'd, or at leaſt in one of them. If any remains after the Shock, the two Bodies will move the ſame way; and the Quantity of their Motion will be equal to the Exceſs of one above the other before the Shock.*

Exper. I. *With two Bodies whoſe Maſſes and Velocities are equal.*

Exper. II. *With two Bodies whoſe Quantities of Motion are in the Ratio of* 1 *to* 2.

Corollaries *or Conſequences from the preceeding Propoſitions.*

Article II. *Of the Shock of Elaſtic Bodies.*

Propoſition I. *When an Elaſtic Body ſtrikes another Elaſtic Body that is at Reſt, or which is moving the ſame way; this after the Shock will move in the Direction of the Body which ſtruck it, with a Velocity compounded of that which was immediately given it, or by Communication, and of that which it acquires by it's Reaction after the Shock; and the ſtriking Body, of which the Elaſticity acts the contrary way, loſes in the whole or in part what it had kept of it's primitive Velocity. And if it's reflected Motion exceeds the Remainder of it's primitive Velocity, it goes backwards according to the Quantity of this Exceſs.*

Exper. I. *With two Bodies of the ſame Maſs, and equal Elaſticity.*

Exper. II. *With two Bodies equally elaſtic, that which is ſtruck having as much Maſs again as the other.*

Exper. III. *With Bodies equally elaſtic, that which ſtrikes having but half the Maſs of the other.*

Propoſition II. *If two elaſtic Bodies, whether equal or unequal in Maſs, ſtrike one another with proper Velocities, which are either equal or unequal; after the Shock, they will ſeparate, and their relative Velocity will be the ſame as before the Shock.*

Exper. I. *With ivory Balls of the ſame Weight, and of equal Velocities.*

Exper. II. *With ivory Balls the Maſſes and Velocities of which are unequal.*

Corollaries *or Conſequences from the preceeding Propoſitions.*

The End of the TABLE of CONTENTS in this Volume.

A
VOCABULARY,
OR
EXPLANATION
OF
Some TERMS in Geometry, which are made Uſe of in this Werk.

ANGLE, is the Opening of two Lines which meet one another in a Point, as A C, B, C, *Fig.* 1. The Point of Concourſe C is call'd the Vertex of the Angle, or the Angular Point. We chiefly diſtinguiſh three Sorts of Angles; that is, the *Acute Angle*, the *Right Angle*, and the *Obtuſe Angle*. The Acute Angle is that which by it's opening includes leſs than the Quarter of a Circle, which may be deſcribed upon a Center, being the Vertex of the Angle; as A C B, *Fig.* 1. The Right Angle is that which by it's opening comprehends juſt a Quarter of the Circle; as A C D. And the Obtuſe Angle is that which by it's opening contains more than a Quarter of the Circle; as A C E.

Angular, which has one or ſeveral Angles. This Term is ſometimes uſed to ſignify, that a Body is cut ſeveral ways.

Arch, is a Part of the Circumference of a Circle. As the whole Circumference is divided into 360 equal Parts. Arches are diſtinguiſh'd by the Number of theſe Parts or Degrees which they contain. Thus, when we ſay, an Arch of 10, of 30, or of 50 Degrees. That which contains juſt 90 is commonly call'd a *Quadrant*, or Quarter of a Circle. As when there are 180 Degrees, it is commonly call'd a *Semicircle*. Such are the Arches A B D, A D F, *Fig.* 1. The Name of Arch is alſo given to the Parts of all other Curves, which are not Circular. As we ſay the Arch of a Parabola, of an Ellipſis, *&c.*

Area, The Surface or Space included in any Figure whatever. The Area of a Circle, for Example, is the Extenſion or Space comprehended by the Circumference.

Atmoſphere, Vapours or Exhalations which exude out of a Body, and ſurround it uniformly to a certain diſtance. This Word is commonly underſtood of the Maſs of Air, which ſurrounds the Terreſtrial Globe, and receives whatever exhales from the Earth continually.

Axis, a right Line which is ſuppoſed to be immoveable, while the Body which it paſſes through makes a Revolution about it. The Axis of a Sphere or a Globe is a right Line which paſſes through the Center, and is terminated at two oppoſite Points of the Surface, which are call'd *Poles*. The Axis of a Cone is alſo a right Line which begins at the Vertex, and ends at the Center of the Baſe; as I K in *Fig.* 2.

Baſis, That which ſerves as a Foundation or Support for any Body, or any Machine. We call the Baſe of a Cone or a Pyramid, the loweſt Plane which terminates it; as the Circle repreſented by L M K, *Fig.* 2.

Center, the Middle, or the Place that is equally diſtant from all the oppoſite and correſponding Parts of the ſame Body. The Center of a Circle is a Point equally diſtant from all the Points in the Circumference; as C, *Fig.* 1. The Center of a Sphere or Globe is the Point equally diſtant from all theſe in the Superficies. We ſometimes give the Name of Center to a Point which is not equally diſtant from all thoſe which terminate the Figure; it is enough if it divides all it's Diameters into equal Parts. Thus P may be conſidered as the Center of the Ellipſis, as it is repreſented by *Fig.* 3.

Circle, a Figure terminated by a Curve-line, of which all the Points A, D, F, G, *&c.* are equally diſtant from another Point C, which is call'd the *Center*, *Fig.* 1. It has been agreed to divide every Circle, great or ſmall, into 360 equal Parts, call'd *Degrees*. So that theſe Parts are always proportional, that is, greater in greater Circles, and leſs in leſs, but always of the ſame Number in every one. Every Degree is ſubdivided into 60 *Minutes*, and every Minute into 60 *Seconds*, and every Second into 60 *Thirds*, *&c.* In the Sphere are diſtinguiſhed two Sorts of Circles, great and ſmall. The firſt are thoſe the Diameters of which paſs through the Center of the Sphere; ſuch are the Equator, the Horizon, the Zodiack, *&c.* Thoſe are call'd leſſer Circles, the Planes of which do not divide the Sphere into two equal Parts; or, which is the ſame Thing, the Center of which is not the ſame as the Center of the Sphere. Such are the Polar Circles, and the two Tropicks.

Circumference, a Curve-line which returns into itſelf, which terminates and includes a certain Space. Such is the Line Q T R S, *Fig.* 3. or A D F G, *Fig.* 1. Very often the Circle is confounded with it's Circumference; yet, to ſpeak properly, the Circumference is the Line that terminates, and the Circle is the Space terminated.

Circular, that which has the Form of a Circle, or which is made by a Revolution about a Center. As the Motion of a Sling is circular.

Concave, that which is hollow and round. The Inſide of a Cap or Hat is concave.

Concentric, which has the ſame Center. The Circle *n o b*, *Fig.* 4. is Concentric to N O H, becauſe the Center C is common to both.

Cone, a ſolid Body form'd by the Revolution of a right Line fixed at one end, and which by the other deſcribes a Circle, the Radius of which is leſs than itſelf. This is the Form uſually given to a Sugarloaf; ſee *Fig.* 2. The Point I is call'd the *Vertex* or *Point* of the Cone; the Line I K it's *Axis*; and the Circle L M K it's *Baſis*.

Conical, which has the Figure of a Cone, or which belongs to a Cone. The ſeveral Figures which are produced by cutting a Cone with a Plain, are call'd *Conic Sections*.

Converging, is ſaid of two or more Rays of Light, which are tending towards the ſame Point, to be united there. Thus if A C, B C, *Fig*. 1. were two Rays of Light, proceeding from the Points A and B; their Convergency would be in C, and the Degree of this Convergency would be expreſs'd by the Angle A C B.

Convex, curved or arched, as the external Surface of a Globe.

Cord, as a Term of Geometry, is a right Line, the Extremities of which terminate an Arch of a Circle, as N O, *Fig*. 4. This Line is alſo call'd a *Subtenſe*. If the Arch which it meaſures were half the Circumference, or if it paſſed through the Center of the Circle, then it will be call'd the *Diameter*.

Cube, a regular Solid, terminated by ſix equal ſquare Faces; Dice to play with are ſmall Cubes. See *Fig*. 5.

Cubical, which has the Dimenſions of a Cube. A cubic Foot expreſſes a Quantity of Matter, contain'd under ſix Faces; each of which is a ſquare foot.

Curve, is ſaid of a Line of which all the Parts are not in the ſame Direction. Such is the Arch A B D, *Fig.* 1. We alſo call that a *curved Surface*, of which all the Parts are not in the ſame Plain. Such is that of a Globe, of a Cylinder, *&c.*

Curvilinear, which is compoſed of curve Lines.

Cylinder, is a Solid which is compos'd of circular Plains, all equal and parallel. The firſt and laſt of theſe Circles are call'd the Baſes; and the Line AB, paſſing through all the Centers, is call'd the Axis of the Cylinder. See *Fig.* 7.

Cylindrical, which has the Form, or Dimenſions of a Cylinder: This is to be underſtood as well of a Cavity, as of a ſolid Body. The Body of a Pump within ought to be truly cylindrical.

Diagonal, a right Line, which paſſes from one Angle to it's oppoſite, in a Figure of ſeveral Sides. Such is U X, *Fig.* 6.

Diameter, a right Line which divides a Circle into two equal Parts. As G D, *Fig.* 1. We call alſo by this Name ſuch Lines as paſs through the Centers of other Figures; as S T, *Fig.* 3. or U X, *Fig.* 6. Circles are meaſur'd by their Diameters, as alſo all other Figures; and all the regular Bodies which are compoſed of Circles. Thus Cylinders and Spheres are compared by their Diameters.

Diverging, is ſaid of two Rays of Light, which proceed from the ſame Point, and continually depart more and more from each other; as C A, C B, proceeding from the Point C, *Fig.* 1. Divergency is meaſur'd by the Angle made by the ſeparating Rays.

Equilateral, which has it's Sides equal. Such is the Triangle CDE, *Fig*. 8. compos'd of three equal Lines. That Side on which the Triangle ſtands is call'd it's Baſe, and the oppoſite Angle or Point is call'd it's Vertex.

Excentric, which has not the ſame Centre. The Circle *o b i*, *Fig*. 4. is excentric to the two others of the ſame Figure, becauſe it's Center D is not the ſame as theirs, which is in C; and the Diſtance between C and D is the Meaſure of this Encentricity.

Globe, or *Sphere*, is a regular Solid, of which all the Points in it's Surface are equally diſtant from a common Center. See *Fig*. 9.

Globule, or little Globe. This Word is often uſed to ſignify a ſmall Body round on all Sides. Mercury, when ſeparated, parts into Globules. The little Particles of Air appear in Water in the form of Globules.

Hemiſphere, half of a Sphere or Globe. We often mean by this Word, that part of the Earth which is terminated by the rational Horizon. The Sun every Day enlightens our Hemiſphere.

Hexagon, which has ſix Sides or ſix Faces. We ſay an Hexagonal Plain, an Hexagonal Pyramid.

Horizontal, parallel to the Horizon. This Word determines the Poſition of a Plain, or of a Line.

Incidence, ſignifies the Falling or Direction of a Line upon another Line, or a Plain. We call that the Angle of Incidence which is form'd by this Meeting.

Line, is a Succeſſion of Points as near as poſſible to one another. If the Points are in the ſame Direction, they make a right Line, as E F, *Fig.* 10. If not, they make a Curve-line, as E G F. We may conceive all Curve-lines as compoſed of infinitely little right Lines, inclined infinitely little to one another, as *E f*, *f g*, *g h*, *i k l*, *Fig.* 10. In this Senſe there will be properly no Curve-line.

Obtuſe, is ſaid of an Angle which has more than 90 Degrees. See *Angle*.

Parallel, is ſaid of a Surface, or of a Line, which in it's whole extent is equally diſtant from another Surface or another Line. The Lines X *x* and U *u* are parallel to each other; *Fig.* 6.

Parallelogram, a plain Figure, of which the oppoſite Sides are parallel to one another. Such is *Fig.* 6.

Pentagon, a plain Figure terminated by five Sides.

Perpendicular, in ſpeaking of a Line or Surface, ſignifies, that it has ſuch an Inclination to another Line or Surface, that it makes with it two right Angles, or one at leaſt. The Line H I is perpendicular to L M, *Fig.* 11.

Plain, an Extenſion or Superficies that is ſtrait and ſmooth, terminated by one or ſeveral ſtrait Lines or Curves. *Fig.* 1. repreſents a circular Plain. *Fig.* 6. repreſents a ſquare Plain.

Point, the leaſt extended Thing poſſible; the Dimenſions of which cannot be diſtinguiſh'd. This is rather call'd a *Phyſical Point*.

Pole, one of the Extremities of the Axis, about which Revolutions are made. The Poles of the World are two immoveable Points, about which the Revolution of the whole Sphere is perform'd.

Polygon, a Figure that has many Sides. This is a general Name, of which the Species are a Triangle, a Square, a Pentagon, a Hexagon, *&c.*

Priſm, a ſolid Body terminated at the two Ends by two plain Polygons, which are equal, like, and parallel, and as to it's length, by ſo many Parallelograms as there are Sides in the two Polygons, which are call'd its *Baſes*. When theſe two Baſes are Triangles, the Priſm is ſaid to be *Triangular*. Such is that as is repreſented by *Fig.* 12.

Priſmatic, which has the Figure of a Priſm, or which has ſome relation to a Priſm. Thoſe are call'd *Priſma ic Glaſſes*, which are made uſe of to ſeparate the Rays of Light. Alſo the colour'd Rays of Light, which the Glaſs Priſm makes us perceive, are ſometimes call'd *Priſmatic Colours*.

Pyramid, is a ſolid Body of ſeveral Faces, and which riſes into a Point, *Fig.* 13. The Cone may be conſidered as a round Pyramid.

Quadrilateral, a Figure terminated by four right Lines. *Fig.* 6. is a regular quadrilateral Figure.

Radius, or *Ray*, ſpeaking of a Circle, is a right Line drawn from the Center to the Circumference. Such is C B, or C D, *Fig.* 1. The Radius of a Circle is alſo call'd it's Semi-diameter.

Rectangle, is ſaid of a Figure which has one or more right Angles. The Triangle V X *v*, *Fig.* 6. is it rectangular, becauſe one of it's Angles *v* is a right Angle.

Rectilinear, which is compos'd of right Lines. The two Triangles or the Square, *Fig.* 6. are rectilinear or right-lined Figures.

Sector, is a Triangle form'd by an Arch and by two Rays. Such is A B C, *Fig.* 1. The Sector of a Sphere is an erect Cone, the Baſe of which is terminated at the Plain of a Segment.

Segment, is a Portion of a curve-lined Figure terminated by an Arch and by a Chord. O Z N, *Fig.* 4. is a Segment of a Circle. We alſo ſay the *Segment of a Sphere*, to expreſs the Part which is contained by a Portion of the convex Surface, and by a Plain which does not paſs through the Center. 'Tis in this that a Segment differs from an Hemiſphere.

Sine, is a right Line which is drawn from the Extremity of an Arch of a Circle, perpendicularly upon the Diameter which paſſes through the other Extremity of the ſame Arch. This is call'd the *right Sine*, as H K, *Fig.* 1. But the Part of the Diameter cut off by the right Sine as far as the Circumference, is called the *verſed Sine*, or *Sagitta*, as K G. And the whole Radius or Semi-diameter is the *Sine total*, or the greateſt of all the Sines.

Sphere. See *Globe*.

Spherical, which has the Figure of a Sphere; as a Ball which is perfectly round on all Sides.

Spheroid, a ſolid Body which approaches nearly to the Figure of a Sphere, but is not perfectly round on all Sides, having not all it's Diameters equal.

This is the Figure which is now attributed to the Earth.

Square, a Figure of four Sides, having it's Angles right. If it's four Sides are equal, it is call'd a *perfect Square*. If it has two Sides long, and the other two ſhort, which are oppoſite to each other, it is call'd a *long Square*. *Fig*. 6. is of the firſt kind.

Triangle, a Figure comprehended by three Lines, which from three Angles, C, D, E, *Fig*. 8. Triangles receive different Names, according to the Nature of the Lines and Angles which compoſe them. Thus we call that a *right-lined Triangle*, which is compoſed of right Lines, *Curvilinear*, if compoſed of Curves, *mix'd* when partly of each: *Rectangular*, when one *Angle* is right; *Equilateral*, when all the Sides are equal, *&c.*

Vertical, is ſaid of that Point of the Heaven which is directly over our Heads, and is otherwiſe call'd the *Zenith*. A Line falling ſtrait from this Point is neceſſarily perpendicular to the Horizon. Wherefore we ſometimes uſe this Word to expreſs a Direction which ſalls at right Angles upon an horizontal Plain.

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LECTURES IN Experimental Philoſophy.

LECTURE I.

INTRODUCTION.

NATURAL Philoſophy is the Science of Body. It's Object is to know the Productions of Nature by their Properties, by the Effects they exhibit to our Senſes, and by the Laws according to which their mutual Actions are performed. 'Tis in this chiefly that it differs from Natural Hiſtory, which only informs us what are the Productions of Nature, and the ſenſible Differences by which they are characterized, according to their ſeveral Kinds and Species.

We call *Natural Bodies* all the Material Subſtances, the Collection of which compoſes the Univerſe.

What we obſerve in them to be uniform and conſtant, of which we do not perceive the Cauſes, we call *Properties*; and we ſet out from hence, as from a fixt Point, to explain the different Phænomena; not daring to aſſure ourſelves, that what we aſſign as a firſt Phyſical Cauſe, may not be the Effect of ſome other Principle, which is unknown to us.

IF we were certain of having entirely exhauſted the Nature of Body; if we knew beyond all Doubt, that it had no other Properties, but thoſe which already are come to our Knowledge; we might juſtly boaſt of having a compleat Idea of it, and we ſhould have nothing elſe to do but to make Applications, in order to give a Reaſon of the Natural Effects, which are the Object of our Study. But we are very far from being able to preſume ſo much. We certainly have no Right to make ſuch a Suppoſition. That Experience, which has taught us what we know of theſe Properties of Bodies, is ſo far from telling us that it has nothing more to teach us, that it ſeems, on the contrary, to promiſe us an inexhauſtible Source of new Diſcoveries, even by thoſe very Experiments we make every Day.

THO' Phyſicks cannot boaſt of knowing all that Bodies have in common amongſt themſelves, or whatever is particular in every one; yet it knows a certain Number of Attributes, which it looks upon as primary, till it perceives a prior Cauſe, of which they are only the Effects, and which is found in a general and abſolute manner, in whatever is material. Such, for Example, is actual Extenſion, Figure in general, Capacity of Moving, *&c.* which are connected with all Bodies in an inſeparable Manner, in whatever State or Circumſtances they may exiſt.

THERE are Properties of an inferior Order, which do not belong to all Bodies, but as they are placed in certain States and Circumſtances. Theſe are commonly nothing but Combinations of the former, and make a ſecond Claſs. Such for Example is Liquidity or Fluidity, which probably depends on the relative Motion of the ſeveral Parts, or on their Figure, Magnitude, *&c.* So that thoſe Subſtances only can be called Fluids, which are in ſuch a particular State: Thus Fluidity is the Property of Water which can run, and not of Ice, though it be the ſame Body.

LASTLY, Theſe Properties of the firſt and ſecond Order are more and more combined, and ſo belong to a leſs and leſs Number of Bodies. Then they are no longer extended to all, as the firſt are. They do not involve certain Conditions, as the ſecond. They are limited to certain Kinds, Species, and even to Individuals themſelves. Such are many Properties of the Air, of Fire, Light, Metals, of the Load-Stone, *&c.* Therefore we ſhall firſt treat of the more general Properties, and then we ſhall proceed to reckon up thoſe which are peculiar to certain Bodies.

SECTION I.

Of the Extenſion and Diviſibility of Bodies.

THAT which firſt preſents itſelf to our Ideas, or at leaſt to our Senſes, when we examine the Bodies that ſurround us, is their *Extenſion*, that is to ſay, a limited Magnitude of any Shape, in which we conceive Parts diſtinguiſhable from one another.

MATERIAL Extenſion, which is what we treat of here, has three Dimenſions, *Length*, *Breadth*, and *Depth*, which Geometricians conſider and meaſure ſeparately one from another, but which in Phyſicks are inſeparable. For, the ſmalleſt Body is ſolid; it has at leaſt two Surfaces really diſtinct; and as the Depth is compoſed of Surfaces, and that theſe Surfaces reſult from a Collection of Lines; it follows that the leaſt of all Bodies is long, broad, and deep.

ALL the greater Bodies, I mean thoſe which are ſufficiently extended to be viſible or palpable, may be divided into ſeveral Portions, which continually decreaſe in Magnitude, as the Diviſion increaſes; till at laſt every one of them is too little to be perceived by our Senſes. Thus the File reduces, as it were, to a Powder a Piece of Metal, which the Chiſſel has ſeparated from the groſs Maſs.

How ſmall ſoever theſe Particles of Matter may appear to us, we are eaſily convinced that they are ſtill diviſible. The Arts inform us by a thouſand different Proceſſes, that theſe little Bodies are themſelves a Collection of Particles, or little Maſſes that are ſeparable from one another. A Grain of Wheat which the Mill-Stone grinds into Flour, is ſtill farther ſubdivided in the Water, which aſſiſts it's Fermentation.

These Particles themſelves, which are only ſenſible when there are many of them together, and which our Eyes can hardly diſtinguiſh from one another with the beſt Microſcope, are farther decompounded on many Occaſions, and inform us in a very convincing manner, that they have Parts which may be ſeparated from one another, and which very often have no Reſemblance to one another. A Piece of Wood put into the Fire ſoon ceaſes to be Wood. Not only the Particles which make up it's Maſs are diſunited, but thoſe very Parts which Nature had connected together to form theſe Particles, yield alſo to the Action of the Fire, and appear ſeparately under the Form of Smoak, of Flame, of Aſhes, &c.

Finally theſe laſt Parts, which are often different from one another, but the Union of which formed little Maſſes like one another in the ſame whole; theſe Parts (I ſay) are not yet ſuch Things as we may conſider as abſolutely indiviſible. Tho' ſometimes the Name of *Principles* is given them, 'tis rather a Denomination they have received from Cuſtom, than a Character upon which we may rely, in attributing to them a real Phyſical Indiviſibility. We have Reaſon to believe, that in the State in which they generally preſent themſelves, they have not acquired the laſt poſſible Degree of Smallneſs. They have their *Elements*, and theſe Elements are ſtill of a different Nature in moſt of them. Such, for Example, is Sulphur, which heretofore was looked upon as a Subſtance which is unalterable, made uſe of by Nature in the Compoſition of Bodies; which a more perfect Phyſicks has ſince found means to decompound, and even to imitate.*

But after we have exhauſted all our Endeavours to divide any Part of Matter, and all our Proceſſes fail us, and Experiment refuſes to inform us better; What ought we to think of the Diviſibility of Body; and what Rule can we follow in our Conjectures? Muſt we think that all is done, and that we have purſued Nature into her laſt Retrenchments, and that we are arrived at thoſe ſmall ſimple Bodies, with which we may ſuppoſe ſhe began that Work, which we have undertook to decompoſe?

It would be Preſumption to think it, and the Difficulties themſelves, which we have met with in our Trials, ought to make us at leaſt to ſuſpect the contrary. When we undertake to divide a Body, the Execution becomes more and more difficult, in Proportion as the divided Parts decreaſe in their Bulk. 'Tis becauſe we cannot ſeparate them, but by making a foreign Matter act upon them to diſunite them, or by uſing external Force to oblige them to ſeparate. The ſmaller they become, the leſs hold they afford to the Means we uſe, and their Diſunion is ſo much the more difficult, the more they reſemble, or the nearer they approach to, their firſt Simplicity; whether they then touch by Surfaces that are more analogous, or that few Bodies are to be found harder and ſmaller than they are, in order to ſubdue them. 'Tis therefore very natural to think, that when Matter can no longer be divided, 'tis not becauſe it has no Parts that are farther diviſible; but becauſe there is nothing ſubtile enough tc diſſolve it's Continuity.

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* Memoirs of the R. Academy of Sciences, for 1704. p. 275.

Is Matter therefore diviſible *ad infinitum?* What we have ſaid hitherto, does not oblige us to make this Concluſion. And this Queſtion, which makes ſo much Noiſe in the Schools, appears to be reduced within a ſmall Compaſs, when Men underſtand one another rightly. For if it is underſtood of a Diviſibility, which is meerly ideal; it is plain we may anſwer in the affirmative; for then the whole will come to this, whether we can conceive a Body always as diviſible, however divided it may already be. But it is certain we can conceive it in this Manner: We ſtill imagine there are two Halves in the ſmalleſt Particle. The Surfaces that comprehend it, tho' infinitely near one another, can never coincide; and we may always ſay the ſame thing, at every new Diviſion that we can ſuppoſe. This imaginary Diviſion therefore has no Bounds, ſo that if Art and Nature could extend ſo far, as to execute all that we can conceive, we might find in the Wing of the ſmalleſt Fly a Number of Parts, which at laſt would be equal to that of the Grains of Sand, which are ſcattered upon all the Shores of the Ocean. A Propoſition which can appear a Paradox only to thoſe, who would confound the Compariſons of Numbers, which only can have Place here, with thoſe of material Magnitudes.

BUT is Nature as fruitful as our Imaginations? That which we conceive as poſſible, does it really obtain in Nature? Suppoſe theſe little Portions of Extenſion, which touch one another without Confuſion, to be really diſtinguiſhed from one another, are they therefore actually diviſible? Have they ever exiſted, or does their Nature allow them to exiſt ſeparately from one another? Upon this, Experience has pronounced nothing that is certain; and as in Natural Philoſophy, Proofs drawn from Fact are the only ones that teach us any thing, we may ſay that this Queſtion is undecided.

YET many Philoſophers, by ſuppoſing Limits to this Phyſical Diviſibility, have taken upon them to ſay, that the Elements of Bodies are abſolutely indiviſible, and that Nature in forming them had impoſed as it were a Law upon herſelf, never to ſuffer them to be divided. For a Proof of this, they alledge the Experience of ſix thouſand Years. 'Tis on this account, ſay they, that the natural State of things has always ſubſiſted the ſame from it's firſt Original. An Oak is an Oak for ever, a Horſe at this Day is what it was at the Beginning. If the Buds, or that which conſtitutes every Nature in particular, was a thing diviſible, would not Nature in general have changed her Face, by the ſeveral Mutations that every particular Species muſt have ſuffered?

THO' I am more inclined to admit the Being of *Atoms*, or inſeparable Corpuſcles, than to ſuppoſe Matter phyſically diviſible *ad infinitum*; yet I cannot diſſemble, that the Argument I have now brought, as ſpecious as it may appear, is not of Force ſufficient to decide the Queſtion, and that a ſubſtantial Anſwer may be given to it. For though theſe little Beings, the immediate Productions of Creation, were not indiſcerpible as is ſuppoſed; would not the Author of Nature have ſufficiently provided for the Continuation of his Works, by ſuffering only ſuch Means to exiſt in the World, as are unable to diſorder the Œconomy of it? Let it be proved then, that an abſolute Indiviſibility of the primary Parts, is the only way that the Wiſdom of the Creator could have taken, to render each Species unalterable. But if this admirable Uniformity, with which we ſee Nature to be reproduced every Day, is not an invincible Proof of the Exiſtence of Atoms; it ought at leaſt to make us think, that we ſhould not ſo eaſily ſuffer ourſelves, at our own Humour, to change one Manner for another. All the Means that Art can furniſh us with for ſuch Operations, would be but feeble Imitations of Nature, of her Digeſtions, Fermentations, Calcinations, *&c.* And if Nature herſelf, ſince her Original, has been conſtantly preſerved without any Change, notwithſtanding all the Motions which have been produced in her own Boſom, and are ſtill produced every Day, ought we to flatter ourſelves, that we can work Miracles in our Laboratories? Chemiſtry itſelf, tho' more ſkilful now than it ever was before, for this very Reaſon gives up more and more this Kind of chimerical Purſuits, to apply itſelf to Operations of more real Utility. It decompounds the Productions of Nature as far as it can, in order to know their Properties; it makes Extractions of them, which it converts to our Uſe; and if it endeavours to imitate Nature, 'tis no longer by attempting to compoſe Subſtances, which ſhe cannot flatter herſelf ſo much as to know.

From what we have now ſaid concerning the Diviſibility of Bodies, it reſults firſt, that there is no Limit to this mental Diviſion, which requires nothing in Matter but a real Diſtinction of Parts. Secondly, that a Phyſical Diviſibility, poſſible or not poſſible, *ad infinitum*, is nothing but a Syſtematical Affair, in which probable Arguments may be found, both for and againſt the Queſtion. Thirdly, that we cannot deny at leaſt a Multiplicity of Parts, which are actually ſeparable, and ſo ſmall that their Number and Subtilty far ſurpaſſes our moſt refined Notions.

The laſt of theſe three Propoſitions is the only one which is capable of this ſort of Proofs, to which we confine ourſelves in this Work. I therefore appeal to Experiment, and ſhall undertake to make known by Facts worthy of Curioſity, what we ought to think of the prodigious Diviſibility of Body.

EXPERIMENT I.

PREPARATION.

LET us place upon three ſmall Nails, or in any other Manner equivalent to this, a thin Piece of Money of Copper, Silver, or Gold; and under it and upon it let us put ſome Flour of Brimſtone, and ſet it on Fire; as is repreſented by *Fig.* 1.

EFFECTS.

BY this Operation, which ſome bad People abuſe to make counterfeit Money, the Piece of Money will be parted into two, according to it's Plain. And very often one of the two Pieces, being more thin and brittle, leaves the other ſo well marked, as not to appear to be ſenſibly diminiſhed.

EXPLANATIONS.

A Body is divided when the Connexion of it's Parts is diſſolved by a foreign Matter, and which is not ſuited to unite itſelf with them. 'Tis thus that the Blade of a Knife divides a Piece of Wood into two. The more ſubtile Part of the Sulphur, which expands itſelf in burning, and which inſinuates itſelf on all Sides between the Parts of the Metal dilated by the Fire, forms within the Piece, and according to it's Plain, a Layer of Matter foreign to the Metal, which cauſes a Diviſion, and which may be perceived when the Parts are ſeparated.

APPLICATIONS,

THE ſame Cauſe, which diſunites the Surfaces which were joined together, hinders them from joining again, tho' they might have all the Diſpoſitions neceſſary for it. 'Tis therefore for this Reaſon that we make Uſe of Oils and Greaſe, to keep diſtinct ſuch Matters as we would hinder from uniting or mixing; ſomething moiſt to prevent the Adherence of things that are fat; abſorbing Powders, when there is a Fluidity on the Surface which would make them join. Thus, to make Uſe of ſome familiar Examples, we may obſerve, that they make Uſe of cold Butter in Slices for Paſtery-Work, which ought to Part into Leaves; that they moiſten with ſome liquid Matter the inſide of Molds, in which they are to caſt melted Wax, or Sulphur, *&c.* and that they put upon dry Sand, ſuch Veſſels as are newly formed in the Manufactures of Porcelain or Dutch Ware. 'Tis for this Reaſon alſo, that in the Arts they take great Care to cleanſe very well ſuch Surfaces, as they would join together for a Continuance.

THE Uſe of Glues and Solders is no Argument againſt this Propoſition, tho' a foreign Matter is then interpoſed between the Parts that are to be joined.

AS for Example: The chief Reaſon why a little Water dropped between two Pieces of Wax, commonly prevents the Union of thoſe Parts, is that the Water not being adapted to penetrate into theſe unctuous Bodies, and applying itſelf to them but imperfectly, it's Interpoſition cannot ſerve as a common Copula or Cement. But it is not ſo with a Glue, which can penetrate, tho' ever ſo little, into the Pieces which are to be joined together. 'Tis a fluid Body when applied, and which for this Reaſon, can inſinuate itſelf on each Side, into the inſenſible Cavities of the two Surfaces. But it ſoon becomes ſolid, by being forſaken of it's Humidity, which penetrates farther. Then theſe little Bandages, being as many almoſt as there are Cavities between the ſolid Parts of the Surfaces, make a very ſtrong Adheſion. 'Tis on the ſame Principle, tho' with ſome little Difference, that Solders ſerve to join Metals together. A Mixture of Lead and Pewter together, for Example, when put into Fuſion by touching it with a red-hot Iron, penetrates into the firſt Surfaces of the Metal dilated with the ſame Heat; then a ſudden cooling makes the Parts to approach one another. The Solder at the ſame Time loſes it's Fluidity, and adhering on each Side, ſerves as a common Copula to both the Pieces, and ſo joins them.

EXPERIMENT II.

PREPARATION.

In a drinking Glaſs are put ſome ſmall Leaves of Copper; in another like Glaſs is put a little of the Filings of Iron or Steel. In each of them is poured half an Ounce of Aqua Fortis. See *Fig.* 2. 3.

EFFECTS.

IN the firſt Veſſel there ariſes a little bubbling; the Metal appears agitated; it's Bulk apparently diminiſhes; the Liquor becomes hot; it aſſumes a green Colour; laſtly the Leaves diſappear, and a Vapour is ſeen to ariſe above the Glaſs. In the other Veſſel may be obſerved the ſame Effects pretty nearly, but more quick, more violent, and the Colour approaches to red.

EXPLANATIONS.

THE Parts of the Aqua Fortis, which may be conſidered as ſo many little Razors, or ſmall but very ſharp Needles, are hurried among the Parts of the Copper or Iron, by a Force, the Knowledge of which is not yet ſettled by Philoſophers, and concerning which Experience has not yet pronounced in a deciſive manner. Every little Maſs being penetrated on all Sides, diſappears by little and little by the Diviſion of it's Parts, which float independently of each other, in the Liquor, which has diſunited them, and which by their Mixture appears under a Colour, which it had not before the Operation. The Heat, which ariſes during the Diſſolution, is a natural Conſequence of the Motion of the Parts, and of the Action of one Matter upon the other. As alſo the Vapour, which ſenſibly ariſes, is an Effect of the increaſed Heat.

THE ſame thing is produced in the other Glaſs, but more ſuddenly, and with more Violence. The chief Reaſon of this Difference is, that the Aqua Fortis made Uſe of in theſe two Operations, for dividing the Maſſes, has more room to exerciſe it's Action on the Iron reduced to Filings, than on the Copper which is in Plates. It acts ſo much the more as it is applied to more Surface in the ſame time. But the Quantities of the Matters being equal, this preſents more of Surface becauſe more divided. Let us ſuppoſe, for Example, one Ounce of Iron to be collected into a little ſpherical Maſs. If this little Globe is cut according to it's Diameter, it's Surface will be augmented. For it will ſtill have that of it's two Hemiſpheres, and it will moreover have that which is produced by it's Section. And if the Number of Sections is multiplied, 'tis eaſy to perceive, that the Quantity of Surface will be more and more increaſed.

ANOTHER Reaſon, which may be added, is this, that the Copper in an equal Volume is heavier than the Iron. Therefore there is more void in the latter of theſe two Metals, and conſequently a freer Acceſs for the Aqua Fortis, if otherwiſe all things are equal.

As to the Colours that the Liquor aſſumes by theſe Diſſolutions, this is not the Place to ſpeak of them. We ſhall explain this Kind of Effects, when we come to treat of Light.

APPLICATIONS.

COMMON Water, in Reſpect of a great Number of Bodies, does the ſame Thing as Aqua Fortis upon Metals. It diſſolves Earths, Salts, the Juices of Plants, *&c.* It is impregnated with their divided Parts, and keeps them ſeparate, as long as there is a ſufficient Quantity to hinder them from joining again. When Rivers appear turbid after Rains, or after the melting of Snow, 'tis becauſe they then receive into their Channels Waters that are loaded with Earth and Sand. Mineral Springs then aſſume their different Qualities from the Matters they contain, in Particles ſo ſubtile that their Tranſparency is not loſt. And the Sea is ſalt, according to the moſt received and probable Opinion; becauſe it diſſolves the Rocks of Salt, which are at it's Bottom, and are ſuch as are found in other Parts of the Earth.

THIS ſort of Diſſolutions does not decompound Bodies; it does nothing elſe but divide their Maſſes, and makes their little Particles thus diſunited, to be independent of one another. Even Art furniſhes us with very eaſy Methods to reduce them to their firſt Stage. It is enough for the moſt Part to evaporate the Liquor which keeps them in Diſſolution; and this is the ſimpleſt Way, when their Parts are leſs volatile than thoſe of the Diſſolvent. This Practice is in Uſe, to ſeparate the Salt from the Water at the Brine-Pits; to extract the Salt-Petre from the Lee-Aſhes which contain it; to refine Sugars; to increaſe the Strength of Soups and Gellies; and, in general, to thicken all ſuch Matters, in which the liquid Part is too abundant.

We may collect again that which has been diſſolved, by Precipitation. This always happens, as often as we preſent, to the Diſſolvent, a Matter more penetrable in reſpect of itſelf, than that, with which it is impregnated. For, then entering into the new Maſs, it depoſits the other Parts, which their own Gravity precipitates to the Bottom of the Veſſel. As for Example: When we pour Spirit of Wine upon Water, which is ſatiated with Sugar; one of theſe two Fluids penetrates the other, and forſakes the Parts of the Sugar, with which it had before been impregnated.

When we thus precipitate Metals, it may be done after an elegant Manner, and which is not very apt to impoſe upon thoſe who are not verſed in Trials of this Kind. For Example: Dip a Plate of Iron in a Solution of Copper, or of blue Vitriol with Aqua Fortis, the Diſſolvent will act preferably upon the Iron, and depoſit the Parts of Copper, in the Place of thoſe which it will ſeparate from the Maſs of Iron; ſo that at the End of the Operation, we may be able to draw out of the Veſſel a Plate of true Copper. Nevertheleſs it would be an Abuſe of this Experiment, to propoſe it as a Proceſs for converting Iron into Copper; becauſe we ſhall never extract any more of this laſt Metal, than what entered into the firſt Solution.

INFUSIONS properly ſpeaking are nothing elſe but Diſſolutions; but commonly more ſlow: With this Difference however, that inſtead of making the whole Maſs to diſappear, they take from it only a certain Portion.

THE Bodies which we infuſe are generally compoſed of Parts of different Natures. The Liquid that penetrates them, is impregnated with thoſe that ſubmit to it's Action: and the other which refuſe, continue united under a Volume, which differs little from that they had at firſt. *Indian* and *Braſil* Woods, *&c.* ſoaked in common Water, yield a certain Juice, which Nature has placed between the Fibres of thoſe Sorts of Wood: Yet in this Extract, which makes a Tincture, we can perceive no ſenſible Diminution, as to Bulk, in the Pieces of Wood, from whence that Tincture is drawn.

INFUSIONS, that are made with hot Water are both much quicker, and alſo much better impregnated. The Heat increaſes the Fluidity of the Water, and makes it more penetrating. It alſo dilates the Solids, which are immerged in it, and makes them more penetrable. Theſe two Reaſons concur to produce the ſame Effect. The acrid Juices, and other diſagreeable Parts, which by boiling, we take from the Roots and Fruits, that are boiled for our Nouriſhment, could not be extracted from them by cold Water.

THOUGH Diſſolutions and Infuſions, which do nothing elſe but divide or extract, make no Change in the Nature of the Parts which they ſeparate and take away; yet they make them fit for the Effects they are to produce, and which we ſhould expect in vain without one or other of theſe Preparations. What Aſſiſtance would the greateſt Part of the Minerals or Vegetables, which are made Uſe of in Medicine, afford us, if a much more minute Diviſion than could be obtained by cutting them, did not procure to theſe Bodies a ſufficient Quantity of Surface, as alſo convenient Figures and Magnitudes, for the internal Parts of the animated Body, upon which they are to operate? That agreeable Variety of Colour that we admire in Stuffs, and in all ſuch Subſtances as are capable of Tincture, does it not for the moſt Part proceed from Infuſions? Juices which are indurated in thoſe very Plants in which Nature has prepared them, and which would remain there quite loſt to us, are ſoftened and expanded in the Water which penetrates them. With it they inſinuate themſelves, and are ſpread upon a Surface prepared for them. In all which Caſes the Water evaporates; but the Tincture remains.

EXPERIMENT III.

PREPARATION.

THE fourth Figure repreſents a little Perfuming-Pan of Glaſs, partly full of a fragrant Liquor, as Orange Flower Water, or Spirit of Wine in which Lavender has been ſteept; and placed upon a little lighted Lamp.

EFFECTS.

WHEN the Liquor begins to boil, there comes out of the Spout of the Perfuming-Pan a very copious Vapour, which ſpreads itſelf ſo powerfully over all the Room, that it may be perceived from one End of it to the other; yet without ſhewing any ſenſible Diminution in the Quantity of the Liquor, when the Experiment is at an End, which will be in about two or three Minutes.

EXPLANATIONS.

THE Vapour, which conveys it's Scent through all the Room, is nothing elſe but the more volatile Part of the Liquor, which the Fire has ſeparated from the Maſs, and has exceedingly divided. Theſe little Bodies, notwithſtanding that ſmall Diminution in the Quantity of the Liquor, are of a Number ſufficient to expand themſelves equally and to be perceived through a very large Room.

IF we deſire to know nearly, the prodigious Number of theſe odoriferous Particles, and to repreſent, in a more exact Manner, the ſurprizing Diviſion that a ſmall Quantity of the evaporated Liquor muſt undergo; it will be ſufficient to compare it to the Volume of Air contained in a Chamber, which may be about 12 Feet ſquare, and of the Height of 10 Feet. Suppoſe then that this ſmall Quantity of Liquor aforementioned, ſhould be equal to two Cubic

Lines[*], before the Experiment is made, and that, after the Evaporation, there ſhould only remain four Particles in every cubic Line of Air; (a Suppoſition, which may be allowed, ſhould we take things at the leaſt Advantage,) How many Millions of Parts ſhall we preſently find out by this Compariſon, and by this Calculation, which may be eaſily made? But theſe Millions of Parts, how much will they be ſtill increaſed if we obſerve, that That which here makes the Scent to be ſenſibly expanded, is but the leaſt Part of what is evaporated? For, in the Liquor, as well as in the fragrant Vapour, we ought to diſtinguiſh the Parts which are proper to the Fluid, and thoſe which wholly belong to the Perfume.

APPLICATIONS.

If we conſider Odours in Regard to our Senſes, they are Impreſſions made upon the Organ by the Corpuſcles, which exhale from the odoriferous Bodies. That which is only ſhewn in the Little by the laſt Experiment, we find every Day in the Great by divers natural Effects. There is expanded upon our Globe a certain Degree of Heat, which is various according to Time and Place. This Fire lighted up by Nature, and which puts every Thing in Motion, joined to other Cauſes of which we ſhall ſpeak elſewhere, carries off continually the more ſubtile Parts of all the Bodies that cover the Surface of the Earth. Thoſe that are proper to make themſelves be perceived by the Senſe of Smelling, being expanded and floating, as well as the reſt in that Part of the Atmoſphere that is impregnated with them, become ſo much the more ſenſible as they are found more copious in a Volume of Air of a determinate Magnitude. This, no doubt, is the Reaſon, why we ſmell more agreeably the Flowers of a Garden towards the Evening, when the Air is cooler, than in the ſultry Heat of the Day. This Coolneſs, which condenſes the Air at the Approach of Night, by bringing it's Parts nearer together, contracts alſo the Exhalations with which it is loaded, and when we breathe it in this State, it brings with it to the Organ of Smelling, a greater Number of the odoriferous Particles we are ſpeaking of.

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[*] A Line is the twelfth Part of an Inch.

If Heat always keeps up a greater or leſs Quantity of Motion in all Bodies; and if by that, as we cannot doubt, it occaſions a continual Loſs of their Subſtance; Can we wonder that every Thing ſhould decay in Time, and that certain Bodies ſhould leſſen and vaniſh away on a ſudden? 'Tis by this Means that Ponds and Marſhes are dried up, when Rains and Springs do not ſupply their continual Evaporation.

But to confine ourſelves to Examples taken from odoriferous Bodies: Do we not obſerve it in a very ſenſible Manner, in Plants and in Flowers? Why do they grow weak and flaccid under a great Degree of Heat, ſo as to hang their Heads by their own Weight? Why do they look freſh again in the Morning, and appear with their former Vigour? Is it not becauſe that which exhales in the Day-time exceeds that which aſcends from the Earth, in order to repair them? But it is not ſo in the Night-time, when the Vacuities are ſupplied and filled up.

THOUGH Plants by their Exhalations, loſe ſo great a Quantity of their Subſtance; yet we cannot affirm, that the Part aſſigned for propagating their Smell, ſuffers much by this ſenſible Decay. It appears by all other Bodies of this Kind, that Nature has ſubjected them to ſo prodigious a Diviſibility, that they can furniſh out ſufficient for this Purpoſe, during a long Courſe of Time. Every Body knows that a Grain of Muſk will make itſelf ſmell, in a Manner not very agreeable, for a Space of twenty Years, in an Appartment where freſh Air is admitted every Day. It is well known alſo, that Hounds will give Chace to a Stag, ſometimes for ſix Hours, and that very often without having any other Guide, than the Scent that he leaves behind him. How many Corpuſcles then muſt iſſue from this Animal, to trace out it's Courſe, for ſo long a Time, to perhaps forty other Animals, who frequently loſe Sight of him?

THE greateſt Part of Brutes, and eſpecially Dogs, have their Smell exceeding delicate. The Diſpoſition of this Organ, the chief Part of which is without, and the frequent Uſe they make of it, contribute much without doubt to this great Niceneſs, which Mankind are not endued with. But Nature has made us amends by the Touch, which Senſe we enjoy in much greater Perfection. This of all our

Senſes is that, which we make moſt Uſe of, except our Sight, in our Examination of the ſeveral Objects that preſent themſelves to us. But Animals, which touch but very rarely by way of Examination, try with their Noſe whatever their Eyes preſent to them as engaging. For, as they are almoſt wholly employed in the Care of procuring their Suſtenance, and as there is much Affinity between the Smell and the Taſte, it was proper they ſhould ſmell rather than handle their Food.

EXPERIMENT IV.

PREPARATION.

At the Bottom of a great Veſſel of Chryſtal-Glaſs, diluted the Quantity of a Grain of Carmine, and the Veſſel is filled with clear Water, which holds about ten *Paris* Pints *. This is repreſented by *Fig.* 5.

EFFECTS.

The Colour of the Carmine is expanded in ſuch a Manner, as that the whole Quantity of Water appears to be ſenſibly tinged with it.

EXPLANATIONS.

Carmine is a Drug, or a Sort of very fine Lee, which is extracted by Infuſion from Cochineal, and ſome Vegetable Subſtances. The Parts, which have already been divided by the Preparation that has been made of them, yield very eaſily to the Action of the Water, which penetrates and expands them. Inſomuch that they diſtribute themſelves proportionally to the whole Maſs of the Fluid.

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* The *Paris*-Pint contains two Pounds of common water.

To conceive eaſily how much the Matter is divided in this laſt Experiment, it is enough to know the Ratio of the Weight of one Grain to that of ten Pounds, which is as Unity to 92160. But a Quantity of Water weighing a Grain, makes a very ſenſible Bulk, which muſt contain many Particles of the Carmine, in order to be of an uniform Colour. If we ſhould ſuppoſe it to have but 10, the Product above muſt be further multiplyed by 10, which will make 921600 ſenſible Parts in one Particle, which was very inconſiderable before it was expanded in the Water.

APPLICATIONS.

'TIS by the Particles of Matter thus divided and expanded in certain Liquids, that Painters and Dyers ſtain the Surfaces of Bodies, with certain Colours which they can't procure naturally. Thoſe which are painted, are always hid under the Covering laid over them, and are not viſible of themſelves, but by the Layers with which the Pencil has cloathed them. But it is not ſo with ſuch as are dyed or tinged. They are commonly prepared in a Bath, which by the Heat and by the Action of certain Salts, dilates the Pores, and digs an infinite Number of little Cells, fit to receive afterwards the colouring Particles.

'Tis

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'Tis chiefly this Preparation, which makes the Dyes durable, and hinders the Things, which are dyed, from loſing their Colours when they are waſhed. Yet it is not always the colouring Particles that tinge the Surfaces; for we ſhall ſhew, when we come to treat of Light, that the Change of Colour, often depends upon a new Arrangement, which is aſſumed by the Parts of the Surfaces themſelves; as when (for Example) *Aqua Fortis* changes blue Paper into red; or that hot Water makes a Lobſter of a red Colour.

BESIDES the Experiments we have now produced, to prove the great Diviſibility of Bodies; the Arts afford us ingenious Proceſſes, which demonſtrate it in a very evident Manner. We cannot obſerve the immenſe Ductility of Gold and Silver, without much Surprize. The Artificers who by beating and drawing theſe Metals, give them ſuch a Degree of Extenſion, have long attracted the Obſervation of Philoſophers. Mr *Boyle* * is one of the firſt who has made this Remark, that the Quantity of a Grain of Gold beaten into Leaves, can cover a Surface of 50 Inches ſquare. This Obſervation gives us an Opportunity to learn, by a very ſimple Calculation, what an amazing Number of viſible Parts, are in this ſmall Quantity of Metal. The Length of an Inch contains at leaſt 200 viſible Parts; for on Mathematical Inſtruments we often find it divided into 100 Parts, and an attentive Spectator may eaſily take account of the two Halves of every one. Admitting then this Suppoſition, which is a very reaſonable one; a Leaf of Gold of an Inch ſquare may be divided into 200 narrow Columns, and every Column into 200 ſmall Squares. So that the whole Leaf thus divided will give 40000 Parts, which is the Product of 200 by 200.

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* De mirâ ſubtilitate Effluviorum. Cap. 2.

But in a Grain of beaten Gold we find 50 little Leaves equal to that we have now divided. Therefore multiplying 40000 by 50, the Product two Millions, will be the Number of Parts, which we may count with our Eyes, in a Portion of Matter, whoſe Weight is but the 72*d* Part of a Drachm. This Number, prodigious as it is, may ſtill be increaſed to as much more, when we conſider, that every one of theſe Particles of Gold may be ſeen and touched, at leaſt as to it's two Surfaces, or by two oppoſite Planes, of which the Dimenſions are equal.

What we are taught by Leaves of Gold and Silver, concerning the Ductility of theſe two Metals, and the ſurpriſing Diviſibility of their Parts, is yet far inferior to what we may obſerve from thoſe Workmen, who prepare the Silver Thread gilt with Gold, which is made Uſe of in the making of Garniture, Lace, Embroidery, &c. This Art, which ordinary Men make only a Subject of Trade, or ſeek only Supplies of Luxury from it, preſents to the Eyes of a Philoſopher a Scene of Prodigies, which have not eſcaped the Curioſity of Mr *Boyle*, Father *Merſennus*, *Robault*, and many other Naturaliſts, at a Time when it had not arrived at that State of Perfection, which it has ſince attained. M. *de Reaumur* *, who has examined it with that Nicety, for which he is remarkable, gives us the beſt account of it's Beauties, and has diſcovered what is truly wonderful in it. And therefore I ſhall borrow from him, the following Obſervation on the wonderful Extenſion, of which Gold is ſuſceptible, when reduced to Threads.

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* Memoirs of the Academy of Sciences, for 1713. p. 205. &c.

WITH a Quantity of Leaf-Gold, which never exceeds the Weight of ſix Ounces, and which ſometimes is diminiſhed almoſt to one, they cover a Cylinder of Silver, of about 22 Inches long, 15 Lines in Diameter, and of the Weight of 45 *French Marcs* *. They make this gilt Roller, to paſs ſucceſſively thro' Holes in a Plate of Steel, which proceed continually decreaſing; ſo that as it grows longer by the Loſs of it's Diameter, it at laſt becomes as fine as a Hair, and of a Length which is nearly equal to 97 Leagues, each of 2000 Fathoms.

DURING this Operation, the Gold ſpreads itſelf upon the Silver-Thread, in Proportion as it lengthens: So that we may conſider it as a Covering, or a Scabbard, the Parts of which ſuffer no ſenſible Interruption. This gilt Thread, which they call Wire, paſſes afterwards between two Rollers of poliſhed Steel, which ſqueeze it into the Form of a thin Plate, with which they cover a Thread of Silk, for the Uſe of ſeveral other Manufactures. In the Operation of the Rollers, the Wire is farther lengthened by a ſeventh Part; ſo that inſtead of 97 Leagues, which we have before reckoned for it's Length, we ſhould now reckon 111.

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* A *French* Mark is eight Ounces.

SUPPOSING then the Thread to be ſuch as is gilded in the ſlighteſt Manner; here is an Ounce of Gold, which ought to be conſidered under the Form of two ſmall Plates, the Length of each of which is 111 Leagues, or which together are equal to 222 Leagues. But if we farther conſider, that the Wire, in flattening under the Rollers, takes the Breadth of about an eight Part of a Line, and conſequently the two little Plates of Gold, that cover the Silver on each Side; we may ſtill divide their Breadth into two Parts; (for a Line is very eaſily diviſible into 16 ſenſible Portions) thus inſtead of two Plates we may count four, which will be equal in Length to 444 Leagues. In ſuch an Extent as this, how many Fathoms, Feet, Inches, Lines muſt there be! And if we only divide each Line into 10 Parts, what a Series of Cyphers muſt we make Uſe of, to expreſs the Number of viſible Parts in one Ounce of Gold, thus extended by Wire-drawing? The Imagination is too weak for ſuch Numbers; but to give ſome Idea of them, it will be ſufficient to compare the Surface of our Ounce of Gold reduced to Thread, to that of an equal Quantity of the ſame Metal in Leaves. The firſt is to the ſecond in the Proportion of 2380 to 146. But alſo the Thickneſs of the Leaves, little as it is, is always much more conſiderable, than that of the Layer of Gold, which is upon the Thread. The one is hardly leſſened to the thirty thouſandth Part of a Line; but the other is often carried to a Degree of Thinneſs, which exceeds the five-hundred-twenty-five-thouſandth Part of a Line.

In thus Wire-drawing Metals, Art imitates Nature very exactly, as to the Proceſs of it. Before Silk is made into Thread for our Uſe, it has already been made into Thread by the Inſects which ſupply us with it. The Caterpillar, which we commonly call a Silk-Worm, has a natural Wire-drawing Inſtrument, through which it moulds this valuable Thread, of which it makes it's Cod or Shell. Some Perſons* that were curious, and inquiſitive into the Miracles of Nature, have examined the extream Fineneſs of this Subſtance, and have meaſured 300 Ells of it, which did not exceed the Weight of 2 ½ Grains. And Mr *de Reaumur*, carrying his Obſervations ſtill farther, obſerves that the Threads of Spiders, ſuch as they are when immediately produced, and before they are joined together to form their Webs; that theſe Threads (I ſay) in Reſpect of a Hair, are not ſo big as a gilt Wire is, in Reſpect of the firſt Cylinder, from which it was drawn: and that their Diameter hardly equals the Thickneſs of that thin Plate of Gold, that covers the Silver Thread.

The Experiments and Obſervations now produced ſufficiently evince, that all Bodies which fall under the Cognizance of our Senſes, are nothing elſe but Collections, formed by the Concurrence of many leſſer Maſſes, every one of which may ſtill be divided into Particles, which themſelves are alſo capable of Diviſion and Subdiviſion.

When in dividing a Subſtance as far as we are able, we find nothing but what is uniform in all the

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[*] Boyle, de mirâ ſubtilitate Effluv. c. 2.

Particles that compoſe it; we give it the Name of a *Simple* Body. We ſuppoſe that it's Parts are all of the ſame Nature, and call them *homogeneous*, yet without being aſſured that they really are ſo; but till ſome new Diſcovery hereafter, ſhall make us judge otherwiſe.

On the contrary we call thoſe *mixt* Bodies, the Parts of which when ſeparated do not reſemble one another; as Plants, Animals, and many Minerals, in which their Analyſis diſcovers, that many Matters which are eſſentially different, and which we call *heterogeneous*, concur to the Compoſition of one and the ſame whole.

The inſenſible Particles, which conſtitute a continued Maſs, are often joined together in ſuch a manner, that it requires a conſiderable Force to ſeparate them. This Portion of Matter is called a *hard* or *ſolid* Body. This Hardneſs, which properly ſpeaking is only a greater or leſſer Tenacity of the Parts, and which is never abſolutely perfect in any of the Bodies that we know, becauſe it always yields to a Force that is finite: This Hardneſs (I ſay) decreaſes even down to *Fluidity*; that is to ſay, till the natural Coheſion of the Parts is hardly ſufficient to hinder them from complying freely with their own Gravity, when it urges them to move one upon another, and to change the Figure of the whole. Laſtly Fluidity, which begins when the Bodies ceaſe to be conſidered as Solid, increaſes even to Liquidity, which alſo has it's Degrees. We call thoſe *liquid* Bodies, or *Liquors*, which are in ſuch a State, that their Parts having a free Motion one upon another, comply with the

Efforts of their Gravity with a mutual Independance, or yield to the leaſt Force that endeavours to ſeparate them. Their moſt diſtinguiſhing Characters are, to have no other Figures but what we make them aſſume by the Veſſels that contain them; and to range their higheſt Surface, in a Plain parallel to the Horizon. Running Water, for Example, is a Liquor. Smoke that riſes in the Air, and which continually changes it's Form, is a Fluid. And a Stone which is cut with the Strokes of a Hammer, is a ſolid Body.

WE now content ourſelves with defining theſe different States of natural Bodies; becauſe we ſhall have Opportunity elſewhere, to ſpeak of them more at large, when we come to enquire into their Cauſes.

SECTION II.

Of the FIGURE *of* BODIES.

ALL Bodies have a determinate Magnitude; not only thoſe whoſe Dimenſions are the Objects of our Senſes, but alſo the Parts of theſe ſame Bodies, to whatever Degree of Subtilty they may be carried by Diviſion, and under whatever Order they are conſidered. Littleneſs is no abſolute Quality; nothing is little but by a Compariſon with ſomething that is greater; and tho' we ſhould conceive the leaſt of all material Beings, yet it would ſtill be greater than either of it's two Halves.

THE Magnitude, or (which is the ſame thing) the greater or leſſer Extenſion of a Body, is always limited by the Surfaces which comprehend the Quantity of Matter proper to it. This Quantity of Matter is called it's *Maſs*. And the uninterrupted Surface, be it more or leſs, which limits the apparent Magnitude, is called it's *Volume*.

THE Order of Arrangement, which the Surfaces obtain among one another, which terminate the Volume of the Body, is what is called it's *Figure*. As theſe Surfaces can never coincide, and are always diſtinguiſhed by their relative Situation, it is plain, that to be figured, is a Property as common to all Bodies, as it is to be ſolidly extended, or to have ſeveral Parts that are really diſtinct.

But theſe Surfaces may be varied *ad infinitum*, either as to their Magnitude, or their Number, or their relative Arrangement. Wherefore all Material Subſtances, to which it eſſentially belongs to have ſome Figure in general, muſt receive this or that in particular. And they are as variable, and perhaps as much varied one among another, as it is poſſible to combine together, the ſeveral Magnitudes, Number, and Order of Surfaces.

This Property, which may be called *Figurability*, is extended to all Bodies in ſo general a Manner, that it accompanies them in all their States or Conditions: It belongs to thoſe which are in Motion, as well as to ſuch as are at Reſt. It does not belong to Solids only, but Fluids and Liquors have alſo their Figure, which depends upon the Obſtacles that confine them. The Sea, Ponds, Rivers are figured by their Coaſts, Banks, and Shores. Wine receives it's Figure from the Veſſel that contains it; Flame and Smoke from the Air that ſurrounds it, *&c.*

When at the firſt Glance of the Eye, two Bodies appear to be terminated alike, we ſay they reſemble each other in Figure. Thus the Dice of a pair of Tables we call Cubes, becauſe at firſt View, each of them preſents ſix equal Faces to us; and we ſay two

Soldiers

Soldiers are alike, if they are cloathed with the ſame Uniform. But this firſt Reſemblance has very narrow Limits. It only extends to certain general Characters, which will hardly ſtand the firſt View. A more critical Examination ſoon diſcovers an infinite Number of Differences, even in Individuals of the laſt Species. So that we may ſay with good Reaſon, that in all Nature, it is probable there are not two Beings that are perfectly alike; eſpecially if to the Variety of Figure, we join thoſe of Colour and Volume. When we caſt our Eyes upon a Flock of Sheep, they all ſeem to reſemble one another; becauſe we ſtop at the firſt Appearances; but the Shepherd eaſily diſtinguiſhes them from one another, becauſe Cuſtom has made him perceive Varieties. In an Aſſembly of People we do not find two Faces alike, and among ten thouſand, we can diſtinguiſh the Countenance of a Perſon we ſeek for, by a Habit we have acquired of knowing Men, and learning not to confound them.

This prodigious Variety of Figures, multiplied without End, to thoſe who obſerve with Attention, does it belong to none but the greater Bodies, that is, to thoſe we can ſee and touch without being aſſiſted by Art? Or rather does it not belong equally to the Particles of theſe Bodies alſo? Does it not extend to ſuch as eſcape our Sight, and which we know by other Senſes; which are not perceived but when many of them are together, and which Prejudice ſeems to inſinuate to us, that they have no Figure at all, becauſe commonly we are ignorant of their true Figure?

THIS Queſtion is anſwered already by the very Definition we have given of Figure in general. For if it be nothing elſe but an Aſſemblage of Surfaces, which terminate a certain Portion of Matter; it is plain that a Body, how little ſoever it may be, will always be terminated by Surfaces, and conſequently will be endued with a Figure.

THOUGH Experiment cannot confirm this Reaſoning in it's full Extent, and ſhew us Figure every where, we have Reaſon to think it is; yet it will ſhew us ſome that have been long unknown, and which Art has found means to diſcover ſince. And we ſhall be taught by curious Examples, not to imagine there can be any Bodies deprived of Figure; becauſe they are not ſubject to our Senſes.

EXPERIMENT I.

PREPARATION.

HAVING placed the Microſcope, repreſented by *Fig.* 6. at the Light of a Window, or, if it is Night, before the Light of a Candle; ſo that the Mirrour below the Plate by it's Reflexion may illuminate the Hole, upon which the Object-Glaſs falls; we muſt make the firſt Glaſs that carries the Objects to paſs along, upon which are put ſome Grains of Sand, and then make the Body of the Microſcope to deſcend, till we meet with the neceſſary Point of View.

EFFECTS.

HAVING placed the Eye above and very near to the firſt Eye-Glaſs, we may perceive the Grains of Sand to be tranſparent as Chryſtals, of the bigneſs of a Nutmeg, angular, and variouſly cut. *Fig.* 7.

EXPLANATIONS.

WE ſhall explain nothing here of thoſe Effects, which directly concern Opticks; becauſe we ſhall treat of that elſewhere. We ſhall confine ourſelves to thoſe only, which have Relation to the Figure of the Bodies, of which alone the Queſtion is at preſent.

WHEN we fix our Eye upon a Grain of common Sand, it appears as a Point; becauſe we ſee it's Dimenſions confuſedly. But with the help of a Microſcope the Object appears greater. Then we plainly diſtinguiſh Lines, Angles, Cavities, Arches, Surfaces; in a Word, a Figure well terminated, of which we eaſily perceive the Differences when we compare it to any other.

APPLICATIONS.

GRAINS of Sand ought to be conſidered as ſo many ſmall and very hard Chryſtals, prepared by

Nature, and which Art applies with good Advantage to different Uſes. Becauſe they are ſmall and angular, they are commodiouſly applied to the rubbing or cleaning Metals, or any other ſtill harder Bodies, upon which the File or a Steel Edge can take no hold. They are made wet on ſuch Occaſions to encreaſe their Motion, and to hinder them, in continually rubbing one another, from loſing their little cutting Angles, and thereby the Property they have, of cutting or wearing away the moſt ſolid Subſtances.

The Tranſparency of white Sand makes it fit for other Uſes. 'Tis the Baſis of all Kinds of Glaſs-work. The Mixture of ſome Salts, and the Action of a very violent Fire which divides it, and which purges it from it's Droſs, puts it's Parts in a Capacity of joining together, and of forming a Paſte, which is ſuſceptible of all ſorts of Forms. When it cools it aſſumes a Conſiſtence, yet without ceaſing to be tranſparent.

EXPERIMENT II.

Preparation.

Let the ſecond Glaſs of the Object-Bearer be made to paſs under the Eye-Glaſs, on which are put ſome Drops of ſalted Water, which has been ſuffered to become dry.

EFFECTS.

IN applying the Eye to the Microſcope, we may perceive little Lumps which appear under like Figures, as when the Preparation has been made with the ſame Salt. For Example, if we uſe Sea-Salt, or that which is commonly ſerved up at Tables, the Object through the Microſcope will reſemble little Cubes, *Fig.* 8.

EXPLANATIONS.

THE Parts of this Salt, which have been divided by the Water, and which it held in Solution, have fixed themſelves upon the Glaſs of the Object-bearer, while the liquid Part evaporated. Before this Evaporation of the Water, the Aſſiſtance of the Microſcope, was of no Uſe to make them viſible; becauſe then they were too much divided, and too minute to be perceived. But as the Liquor forſakes them, they come nearer to one another, and form Lumps of a greater Volume. And even tho' they were to remain as ſmall as they were in the Water, we ſhall ſhew elſewhere, that in equal Magnitudes, tranſparent Bodies may be better ſeen when ſurrounded by Air, than by any other Liquid, that has more Matter.

EVERY Salt, when cryſtallized, generally affects a Figure, which is proper to itſelf, and which probably depends on the Figure belonging to it's ſmalleſt Parts. Sea Salt, for Example, forms Cubes; Salt-Petre, Needles; Sugar, Globules, *&c. Fig.* 9, 10.

APPLICATION.

THE Uniformity of Figure in the little Lumps, is not a Quality peculiar to Salts. We meet with many other Examples of it, eſpecially in the Mineral-Kind. Rock-Cryſtal, and the greateſt Part of tranſparent Stones, often appear in little what they do in great, under the Form of a Priſm, or of an Hexagonal Pyramid. But we muſt not conclude from a particular Caſe to a general, that the inſenſible Parts of all Bodies are ſo many little Models of thoſe, which are in a greater Volume.

BECAUSE of the extream Diviſiblity of Salt, and the angular and pointed Figure of it's Parts, it eaſily inſinuates itſelf into the Pores of all Animal, Vegetable, Solid, or Liquid Bodies; and for this Reaſon it is uſed with Succeſs in order to preſerve them. For, Corruption being nothing elſe but a Diſlocation of the Parts, which changes the Condition of the little Lumps in mixt Bodies; whatever can keep theſe Parts in the Order they have received from Nature, will of neceſſity prevent, that the little Compounds, which reſult from their Aſſemblage, ſhould be altered. And, on the contrary, whatever ſhall promote the internal Motion of thoſe leaſt Parts, will be the Occaſion of Corruption. But the ſaline Particles, as ſo many little Wedges, fill up the little Vacancies, ſtrengthen and ſupport the Solid Particles, ſtop the Progreſs of Evaporation, and preſerve at leaſt for ſome time the natural State. By this Means it is, that the Fleſh of Animals, when ſalted, remains for a long time fit for Uſe; and that Fruits, preſerved with Sugar, will keep for many Years.

THIS prodigious Variety of Figures, which may be obſerved in all inanimate Bodies, and in the little Maſſes that compoſe them, is not leſs numerous nor leſs wonderful in Animals themſelves. The ſame Inſtrument, which has ſhewn us the Angles and Points of ſaline Particles, diſcovers alſo to us a new World of little living Creatures; of little Inſects, which we ſhould hardly ever have ſuſpected to exiſt; of which certainly we ſhould never have gueſſed at the Forms; and which yet we ſhould be curious to know. Wherefore I ſhall add the following Experiment, to ſhew compleatly, how much Nature has varied the Figure of Bodies of all Kinds.

EXPERIMENT III.

PREPARATION.

LET the third Glaſs of the Object-Bearer be made to paſs under the Object-Glaſs of the Microſcope, upon which with the Point of a Tooth-Picker is put a little Drop of one of the Liquors, of which we ſhall here give the Preparation.

1. In a Veſſel with a pretty large Mouth, let a little chopt Hay be put to ſoak; or ſome Straw, or Flowers of different Sorts, and Parts of any Plants whatſoever. Let it be expoſed for about a Week to the free Air, but in the Shade in hot Weather. But if it is not convenient to ſtay ſo long, Water may be taken out of Places where there is green Moſs, or any other aquatick Plants.

2. Expose ſome common Vinegar in a Glaſs Phial, which muſt be kept open.

3. Keep ſome Oyſter-Liquor for three or four Days in a Drinking-Glaſs, or in any ſuch like Veſſel.

Effects.

In the firſt Liquor we may perceive an infinite Number of little Animals, which ſeem to be of different Species, either as to their Figures, or to their manner of moving, which is in great Variety. Some of them, which are like to little Balls (*a*, *Fig*. 11.) dart out in a Right-Line, and always make Angles well expreſſed, when they change their Direction. Others, (as *b*) which are longer, and of an oval Form, do nothing but whirl about. Many of them plainly ſhew their Paws, often a cloven Tail, and other Parts. Others, (as *c*) are compoſed of Rings, and move after the Manner of Earth-Worms, or like Leeches. In others we may perceive the principal Organs, and the Circulation of the Juices. And, if we do but obſerve with a little Attention, we ſhall ſoon diſcover even the final Cauſe of theſe Motions. For we ſee ſome of them devour others; and it is eaſy to perceive, that ſome move to take their Prey, and others to avoid being taken.

Fig. 12. IN the Vinegar, which has been expoſed to the Air for ſome Days in mild Weather, we may ſee very lively Inſects, whoſe Shape nearly reſembles ſmall Eels. It very ſeldom happens that we ſhall find them mingled with Animals, that can be judged to be of another Species.

Fig. 13. The Oyſter-Water contains an infinite Number of little Animals, which are like one another in Figure, and in their Manner of moving. The little Drop, in which they float, ſeems like a Baſon, in which we may obſerve a prodigious Swarm of Carps without Fins or Tails; and ſo tranſparent in their Bodies, that we may eaſily perceive their inward Parts.

EXPLANATIONS.

NATURE has varied the Figure of the ſmalleſt Animals as much, or perhaps more, than that of great ones. But in thoſe, as well as in theſe, ſhe is always conſtant and uniform in every Species. Thus Vinegar, when prepared as directed above, ſhews us Eels, which differ only in Bigneſs from common Eels. And Oyſter-Water generally contains ſuch Animals only as we have ſpoken of before.

YET the firſt Liquor contains Animals, which have no Reſemblance, either in Figure or in their Manner of moving. But this is no Reaſon to conclude,

clude, that the Figure of theſe little Creatures, is the reſult of Chance, and that one and the ſame Species aſſumes this or that indifferently. This Liquor is an Infuſion of ſeveral Sorts of Plants, wherein different Animals may find their Food. And common Water, which is the Baſis of it, is a Medium, which may agree at the ſame time with ſuch Animals, as are fed with Herbs, and with others that are more voracious. The Pike lives in the ſame Water, as the Carp; tho' they feed very differently. And the Hiſtory of Inſects ſupplies us with a Number of Examples, which more directly confirm this Suppoſition. 'Tis not the ſame with the Vinegar, or the Water of Oyſters. It is likely that theſe two Liquors, agree but with a few Species of theſe little Animals; and the Medium they inhabit, may probably ſecure them from being purſued by others. I have many times endeavoured to bring together the Inſects of freſh Water, with thoſe of Vinegar or Oyſter-Water; but the firſt have always died immediately.

APPLICATION.

FOR a long time Inſects were conſidered only as the Offspring of Corruption, and of the Rottenneſs of other Bodies. The Ancients were ſo ignorant of their Original, as to preſume, by obſerving certain ways of Procedure, to attempt their Production by Art; and for this Purpoſe they have even ventured to give Receipts. What popular Prejudice had introduced,

duced, the Philoſophers endeavoured to confirm, and to find a Reaſon for it. The prophane Syſtems, founded upon this Opinion, have not been without Patrons even in theſe our Days. But can the beſt-contrived Hypotheſis keep it's ground againſt Facts, in which Ignorance is hardly to be excuſed? Therefore Our modern Naturaliſts, who are better informed in the Hiſtory of Inſects than they were heretofore, have aſſigned them a more worthy and truer Original. They have made it evident by Obſervations of undoubted Credibility, that the Generation of theſe ſmall Animals is as uniform, and as little equivocal in all their Species, as that of Lions, Horſes, *&c.* They have anſwered by deciſive Experiments, all the ſpecious Appearances, on which that exploded Opinion was founded. We find Worms and Maggots in corrupted Matter; Can it then, ſaid they, be doubted, that theſe Animals are the real offspring of that Corruption? As if we might conclude, that a dead Horſe engendered Crows; becauſe it often happens, that theſe voracious Birds flock together about it. Or that a Paſture produces Sheep; becauſe we ſee them feed there. We might bear with ſuch Suppoſitions, in thoſe that did not know that Birds build Neſts to propagate their Kind, and that a Lamb is always produced by a Sheep. If poſſible, we excuſe thoſe, who at firſt were deceived by ſuch Appearances; becauſe then they might not have the Means of knowing the true Generation of theſe little Animals, ſo different from others by their Size and Figures: But now that it is well known how thoſe are produced, which are viſible enough to be obſerved; it is no longer permitted us to imagine, that Nature, which is ſo conſiſtent with herſelf in larger Productions, takes any other Methods to multiply thoſe, which their extream Minuteneſs will hardly ſuffer us to perceive with a Microſcope; or that ſhe leaves to Chance, the Care of bringing them into the World.

We muſt therefore by no means imagine, that the little Eels we ſaw in the Vinegar, as well as the little Animals we obſerved in the Infuſions of the Plants, are putrified Parts of theſe Vegetables, which are converted into animated Bodies. Experience informs us, that if we keep the Veſſels cloſe ſtopped, nothing will be produced there. But we ought to conclude, that when they are open, the Females carried about by the Air, come thither to depoſit their Eggs or Spawn, as in a place, which may promote their hatching, ſupply them with Food, and make them grow. This Conjecture (if it be no more) may be ſtrongly ſupported by Examples. How many Kinds of Flies do we ſee, that lay their Eggs in corrupted Waters, where the Spawn, after it is hatched, is fed and grows up; and at the ſtated Time of it's Metamorphoſis, it riſes up into the Air, takes Wings and a new Shape, and becomes like to it's Dam?

However engaging this Subject may be, I muſt not purſue it any farther. If the curious Reader would be more amply inſtructed in it, he may conſult M. *de Reaumur*'s Hiſtory of Inſects. There he may contract a larger Acquaintance with this new

People: To ſee them by the Eyes of ſo judicious an Obſerver, is to ſee them well indeed. It is enough for me to obſerve, that if we deſire to attain a thorough Knowledge of that prodigious Variety of Figures, by which Nature has variegated the ſmalleſt organical Bodies; there are no Kinds, which will more gratify our Curioſity, than thoſe of Inſects, in whom we may equally admire, both the Differences, that diſtinguiſh the ſeveral Species, and the Uniformity, which prevails through the whole.

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SECTION III.

Of the SOLIDITY *of* BODIES.

THE Solidity of a Body is nothing elſe but the Quantity of Matter, which is joined together under it's Volume. I ſay, which is joined together. For, if it happens that a foreign Matter ſhould paſs freely through a Body, and ſhould there exerciſe it's Motions independently; as the Water of a River, which waſhes internally a heap of Stones, which it meets with in it's Channel; this Matter would contribute nothing to the Solidity here intended. But, on the contrary, it would increaſe it, if it ſhould be found fixed under the ſame Volume; as if, for Example, the running Water, which we have brought, ſhould become Ice at the Moment that it is found among the Heap of Stones. A Baſket full of Holes, and plunged into a Fluid, has only it's own Solidity. If it be a Piece of Wood, it becomes more ſolid by the whole Quantity of Water which penetrates into it, and unites itſelf to it's Maſs.

To be ſolid is a Property not only common, but even eſſential, to all Bodies; whether they are conſidered in the whole, or whether we have Regard to their ſimpleſt Parts only. This is alſo the leaſt equivocal Sign of their Exiſtence. Optical Illuſions may ſometimes ſo far impoſe upon our Eyes, that we may be tempted to take Phantoms for Realities. But by the Touch we are aſſured of the Truth, from the intimate Perſuaſion we have entertained, that whatever is Body is ſolid, and by Conſequence is capable of Reſiſtance; and that we cannot put our Finger or any thing elſe in a Place, which is already occupied by any other Matter; except we make Uſe of ſo much Force, as is able to remove it.

All Reſiſtance therefore declares a real Solidity, greater or leſſer. This is a Truth ſo little conteſted, that I think it can need no other Proof than the Habit we have got, of confounding the two Ideas; tho' if we would ſpeak juſtly, one repreſents the Cauſe, and the other the Effect. But Caſes may be propoſed, in which each of them, Solidity and Reſiſtance, may eſcape our Senſes, or at leaſt our Attention. There are certain Bodies that touch us inceſſantly, that touch us every where equally. Cuſtom has made their Contact ſo familiar to us, that we muſt reflect upon it, before we are ſenſible of the actual Impreſſion they make upon us. When a Perſon is ſurrounded by a calm and ſerene Air, there are few that conſider they have a continual Reſiſtance to overcome, from a Body, the Solidity of which oppoſes all their Motions. If we were to go out of the

Atmoſphere, and return into it again, we ſhould then perceive without any Reflexion, that the Air touches us on all Sides; as we ſhould feel that the Water touches us, when we plunge ourſelves into it.

Moreover that which makes the Solidity of Fluids to eſcape our Attention, is, the Independency of their Parts on one another, and their extreme Minuteneſs, which exceeds the Niceneſs of our Senſes. So that they yield to our leaſt Efforts, eſpecially when they are in no large Quantity. And we hardly think we act at all, when we act but faintly.

Since Fluids are the only Bodies, whoſe Solidity requires any Proof; and ſince their great Readineſs, with which they yield to any Impreſſion, might give Occaſion to ſuch, as do not attend cloſely to things, to ſuſpect that this Kind of Bodies are not capable of Reſiſtance; they ſhall have the Preference in thoſe Experiments, we appeal to as Proofs: and as the Air is the leaſt ſolid of all thoſe that can be ſhut up in a cloſe Veſſel, let the Experiment be made upon it; that when it's Solidity is fully eſtabliſhed upon Facts, we may conclude *à fortiori* the ſame thing of all other Bodies.

EXPERIMENT I.

PREPARATION.

Into a Veſſel of Cryſtal-Glaſs, repreſented by *Fig.* 14. are poured five or ſix Pints* of fair Water, and a little Piece of Cork A is put to float on the Surface. Then the Veſſel B is made to ſink into it perpendicularly, ſo that the Air, which it contains may not eſcape [at the Mouth A].

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* The Author intends the *Paris*-Pint, which contains two Pounds of fair Water.

EFFECTS.

THE Part of the Surface of the Water, which anſwers to the Mouth of the Veſſel B, ſinks in Proportion as the Veſſel deſcends. The little Piece of Cork, which floats upon it makes this ſinking ſenſible; and ſhews, that no Water enters into the Veſſel B.

EXPLANATIONS.

THE Veſſel B contains a Column of Air, which fills it's whole Capacity. This Fluid Maſs, though conſiſting of but little Matter, is compoſed nevertheleſs of Parts, that are really ſolid, which cannot be diſplaced by another Body, unleſs a new Place is provided for them, to which they may retire. As the Veſſel B is ſhut on all Sides, and as the Water, which is at it's opening, is heavier than the Air, this laſt Fluid cannot leave the Place it is in. And as it's Parts are ſolid, it performs the ſame thing in reſpect of the Water it meets, as any other Body would do, the Parts of which are joined together. Thus the Surface of the Water ſinks as much as the Veſſel containing the Air is made to deſcend; which becomes evident by the Piece of Cork floating thereon.

Tho' the Air of the Veſſel B oppoſes the Water, which endeavours to enter therein, yet it's Reſiſtance is not ſuch as to exclude it entirely. We ſhall ſee elſwhere, that a Maſs of Air is a flexible Body, and that it may be compreſſed into a leſſer Volume when Violence is uſed. We ſhall alſo ſhew, that a Body immerſed in a Fluid, is ſo much the more ſqueezed together, the deeper it is plunged. When theſe two Principles are once admitted, they explain very ſatiſfactorily why the Water riſes a little in the Veſſel B, notwithſtanding the Reſiſtance of the Air. Which Effect would alſo happen, if inſtead of the Air, we ſhould ſubſtitute any other flexible Matter, not capable of mixing with the Water; which we ſhall prove when we come to treat of the Compreſſibility of Bodies. But whatever ſhould happen, and how deep ſoever we ſhould ſink the Veſſel B, the Water would never reduce the Volume of Air to nothing, or take Poſſeſſion of it's whole Place. When once the Violence exerted at the Baſe, have made the Particles approach as near to one another as they can, no Force whatever, can compreſs them into a ſmaller Space. And this is enough to prove, that Fluids like all other Bodies, have an abſolute Solidity.

APPLICATIONS.

With a little Reflexion we may learn from the foregoing Experiment, why we can never fill a Pot, or any ſuch like Veſſel with Water, by plunging it with it's Orifice downwards: Why a Funnel, the Pipe of which fills the Neck of a Bottle too much, is not convenient for pouring Liquor into it: And what obliges us to have recourſe to other Methods, to fill up Veſſels, that are open only by a very ſmall Paſſage, as the Perfuming-Pot in the third Experiment, *Sect.* I. The Prejudice that Cuſtom impoſes on us, by always living in Air, makes us look upon every thing as empty, which is filled only by this Fluid. In this Confidence, ſo ill grounded, we are apt to imagine, that a Liquor, need only offer itſelf any how to the Mouth of a Veſſel, in order to run into it. But we ought to conſider, that all ſuch Veſſels are naturally filled with Air; as they would have been full of Water, if they had been made at the Bottom of a Well, and always continued there. We ſhould conſider alſo, that as the Parts of the Air are ſolid, we muſt not expect it will admit another Body in the ſame Place; and therefore in order to put Water, Wine, *&c.* into a Bottle, the Air muſt paſs between the Neck and the Funnel, to make way for the Liquor. But when the Neck is ſo narrow, that there is not room for a free Paſſage at the ſame time, for two Matters that run contrary Ways; that is, for the Liquor to go in, and for the Air to go out; it muſt be brought about ſucceſſively. Thus to introduce the Spirit of Lavender into the Perfuming-Pot before mentioned, we begin by heating it. And when the Action of the Fire has made a good Part of the Air to go out, which was contained in it, the Neck is plunged into the Liquor, which then takes the Place that the Air had quitted. In this Effect we here conſider only the diſplacing of one Fluid, which is to precede the Introduction of another. When we come to explain the Properties of the Air, we ſhall then ſhew, how a Veſſel that is heated, loſes a great Part of the Air it contains.

We have ſaid already, why the Air cannot eſcape out of the Veſſel B, in the foregoing Experiment. The ſame Reaſon holds good for it's Continuance in the Diving-Bell, where the Divers are ſupplied with ſufficient Air for Reſpiration for ſome time. But 'tis by a contrary Reaſon, that we may conveniently draw the Liquor out of a Veſſel that we have not a mind to remove, with a kind of Pipe ſwelling at the Bottom, as is repreſented by *Fig.* 15. For as this Inſtrument is open at C, the Air eſcapes at this Outlet, as faſt as the Liquor comes in at D. And the next Experiment, will inform us how we may transfer it when full, by making Uſe of the Reſiſtance of the external Air.

EXPERIMENT II.

PREPARATION.

Fig. 16. repreſents a Kind of Fountain, the Pipe of which E F is open at each End. The Part E is raiſed about two Lines above the Bottom of the Baſon G H, which has a Hole at the Centre. The Reſervoir I K, is filled with Water about three quarters full.

EFFECTS.

THIS Fountain runs at ſeveral Intervals, through the little Pipes 1, 2, 3, 4, as long as it is ſupplied with Water by the Reſervoir.

EXPLANATIONS.

WHEN the Pipe E F is open, it gives a free Paſſage to the Air, which exerts it's Preſſure within, upon the Surface of the Water I K. There are then two Cauſes, which concur to the running of the Water; the Preſſure of the internal Air, and the Weight of the Water. Of theſe two Cauſes the firſt is counterbalanced by the Reſiſtance of the external Air, which anſwers at the End of every one of the little Pipes 1, 2, 3, 4, and which oppoſes itſelf without to the Fall of the Water, with a Force equal to the Preſſure, which urges it within. The ſecond Cauſe, which is the Weight of the Water, ſtill ſubſiſts entire, and is ſufficient for the running of the Water. But when the Pipe E F comes to be ſtopt, the internal Air then ceaſing to preſs, the Surface of the Water at I K, ſuffers that without to act freely, the Reſiſtance of which, being too hard for the Weight of the Liquid, the running will ceaſe. They make Uſe of the Water that runs away, and that very ingeniouſly, to cauſe Intermiſſions. As it cannot go out of the Baſon G H, which receives it, but by the Hole at the Centre; there will be enough at firſt, and for ſome Time after, to ſink the Extremity E of the

Pipe; and it will be opened again, and give Paſſage to the Air, only when the Water is run away.

APPLICATIONS.

INTERMITTING Springs are found in many Places, or ſuch where the running of the Water is periodical. Theſe natural Effects, which are to be met with very commonly in the Neighbourhood of Mountains, often depend on a Diverſity of Cauſes, which aſſiſt each other towards the ſame End. But as the different Explications, which are given of them, are generally founded upon certain Properties of the Air, which we have not yet conſidered, we muſt forbear to produce them till the Order we have propoſed in this Work, ſhall require us to treat on this Fluid. We ſhall only ſuppoſe here, what it has in common with all other Bodies, that it is capable of reſiſting and acting upon other Matters. And we find Proofs of it, not only in the Experiments already related, but in many Effects beſides, which our neceſſary Affairs will daily ſet before our Eyes. The Neceſſity of keeping open the Part of the Inſtrument deſcribed above, *Fig.* 15. for ſuffering the Water to enter therein at the Extremity D, will not let us be ignorant of the Reſiſtance of the Air, which would remain incloſed. But if we would tranſport the Liquor we have drawn up, 'tis by a like Reſiſtance made Uſe of without, by which it is to be performed. For, by ſhutting with one's Finger the End of the Canal C, we give room to the external Air, to oppoſe with it's whole Force in D, the Fall of the incloſed Liquid. Lamps and Ink-Glaſſes, the Reſervoirs of which are inverted Bottles, as is repreſented *Fig.* 17. are more, (but ſomething varied) Examples of the ſame Effects. If one ſhould make the leaſt opening in the upper Part L of the Veſſel, the Liquor would then be found between two equal Powers. For, the Air, which would reſiſt in M, would be only in *Æquilibrio* with that, which would preſs at L, and the Oil or the Ink would freely comply with it's own Weight, which would not ſuffer it to remain ſuſpended above it's Level. But as long as the Reſervoir is cloſe at Top, the Air, which oppoſes at M will have ſufficient Force to ſuſtain the Liquor. If a Barrel is full, tho' it may have a Hole at Bottom for a Faucet, yet it would deceive the Expectation of him that made it, if he ſhould forget to give it Vent by a Plug-Hole at the Top. 'Tis likewiſe for the ſame Reaſon, that if a Bottle well corked has a Hole made ſecretly at the Bottom, and is given to any one to uncork; it will much ſurprize him to ſee the Liquor run out ſo faſt.

THE Solidity of Bodies is alſo called *Impenetrability.* But this Term ought to be explained, to prevent ſome Objections drawn from certain Experiments, by which it appears, that ſeveral Matters mingled together blend their Magnitudes, and mutually penetrate one another. A Sponge, for Example, receives within it a Quantity of Water, which ſeems to loſe it's own Volume; becauſe that, under which it is found incloſed, after this Kind of Penetration, does not ſeem to be ſenſibly increaſed. A Veſſel full of Aſhes or Sand, ſtill admits into it a great Quantity of Liquor. And equal Parts of Spirit of Wine and of Water, being mixt in the ſame Veſſel, take up leſs Space therein, than they took up before the Mixture. Is Matter therefore penetrable? Or, if it is not, In what Senſe is it's Impenetrability to be underſtood?

For this we muſt carefully diſtinguiſh between the apparent Magnitude of Bodies, and their real Solidity. The indiviſible Parts, if there are any ſuch, are abſolutely impenetrable. Even thoſe of an inferior Order, which begin to be compounded, are probably never penetrated by any Matter. In a word, in all Bodies whatever, there is a certain Quantity of Parts, which alone occupy the Places they poſſeſs, and which neceſſarily exclude all other Bodies from them. But theſe ſolid and impenetrable Parts, which in reality are the true Matter of theſe Bodies, are not ſo joined together, but that they leave void Spaces between them, or which Spaces are full of ſome other Matter, which has no Connexion with the reſt, and which gives Place to whatever Attempts to exclude it. By admitting theſe little Interſtices, the Exiſtence of which we ſhall prove in the next Lecture, we may eaſily conceive, that the Impenetrability of Bodies, is only to be underſtood of the ſolid Parts, which are found joined together in the ſame whole, and not of the Compound, which reſults from them.

LECTURES IN Experimental Philoſophy.

LECTURE II.

Of the Poroſity, Compreſſibility, and Elaſticity of Bodies.

SECTION I.

Of POROSITY.

THE Poroſity of Bodies is nothing elſe but the Vacuities, which are found among their ſolid Parts. Now, by the Word *Vacuity* or *Vacuum*, we would not be underſtood to mean a Space deprived of all Kind of Matter. There is no doubt but that the greateſt Part of theſe Interſtices contains Fluids, the preſence of which is diſcovered by a thouſand Proofs. When I dip a Sponge, or a ſoft Stone into Water, I ſhall ſee a great deal of Air come out, as far as the Water penetrates into it. And when I make moiſt things dry, they become lighter in Proportion, as they loſe by Evaporation what their Poroſity had admitted into them. Theſe foreign Corpuſcles filled only the greater Vacuities. The Matter of Fire, that of Light, which we ſee paſs into Bodies, which are impenetrable to Air, Water, *&c.* ſuffer us not to doubt but that there are Pores of an other Order, which may be filled by theſe Fluids, which are much leſs groſs than others. But when we conſider the proper Matter of a Body, 'tis always by abſtracting from all thoſe foreign Parts, which are governed by other Laws, and which do not partake in it's Affections. We have alſo Reaſon to beleive, that after theſe firſt Vacuities, which, properly ſpeaking, are not really ſo, ſince they are full of other Matter; that there are other ſmaller ones, which are ſo in the literal Senſe. The Liberty that is neceſſary for Motion, ſeems to require it. But if they truly exiſt in Nature, they are not capable of any Proof by Experiment. Therefore excepting only the ſimple and primary Parts of Bodies, we ſhall fix it as a general Propoſition, that whatever is compoſed of material Parts is porous; hard Bodies as well as Liquids, thoſe that are organized as well as others. And if there is any Difference among them, 'tis only as to the Magnitude, the Number, the Figure, or Situation of the Pores.

EXPERIMENT I.

PREPARATION.

THE firſt Figure repreſents an Air-Pump, on the Plate of which is fixt a Glaſs-Tube N O, terminated at the Top by a wooden Veſſel of Oak P, which has been excavated according to the Grain of the Wood, of which the Thickneſs of the Bottom is about three Lines. Water is put into this Veſſel, and the Pump is made to work.

EFFECTS.

AFTER ſome Stroaks of the Sucker, the Water contained in the wooden Veſſel paſſes through the Bottom, and falls in Drops into the Glaſs Tube. The Wood dilates, and ſometimes the Veſſel cracks.

EXPLANATIONS.

THE Air-Pump is an Engine, the Uſe of which is to pump out the Air, which is contained in a Veſſel. We ſhall not here ſay any thing of it's Conſtruction and various Uſes; becauſe this is foreign to our preſent Purpoſe, and will naturally find a Place in the Lectures, which will treat of the Properties of the Air. It is enough to ſay here, that in making the Pump of this Machine to work, as in the foregoing Experiment, we may exhauſt the Air, which is contained in the Glaſs Tube N O.

A Piece of Wood conſidered according to it's Length, is a Collection or Bundle of ſmall Fibres, included within the Bark, which ſerves as a common Tegument. We may form an Idea of it, tho' indeed a very groſs one, by repreſenting to one's Mind a Bunch of Matches included in a Caſe. How ſmall ſoever theſe ligneous Fibres may be, they can never lie ſo cloſe to one another, but that they muſt leave ſome Interſtices, which will form ſo many little Canals. By excavating the Veſſel in the former Experiment, the Length of theſe Canals was reduced to the Thickneſs of the Bottom, which is not above two or three Lines. Therefore we may conceive this Bottom as a Sieve, open by an infinite Number of little Holes, which paſs from one of the Surfaces to the other. Yet the Pores of the Oak are ſo ſmall, that the Water wherewith the Veſſel is filled, tho' aſſiſted by it's own Weight, cannot find a way through. It muſt therefore have recourſe to a foreign Power, to put it in a Condition of enlarging the Paſſages, that it may then penetrate the Wood. The Force uſed here, is the Preſſure of the external Air, which always acts upon the Surface of the Water, but which cannot have it's Effect till the Reſiſtance is diminiſhed, or made to ceaſe, of that which is incloſed in the Glaſs Tube, and which cauſes an Equilibrium as long as it continues there. Thus after ſome Strokes of the Sucker, the Water preſſed without, being no longer ſuſtained within at N O, filters through the Bottom of the wooden Veſſel, and gathers into Drops, which falling make a Kind of a Shower of Rain.

The Pores could not enlarge themſelves, unleſs the ſolid Parts of the Wood ſhould ſhrink from one another, and ſo the Surface be extended. But if the Circumference, which the Water penetrates leaſt, does not ſtretch proportionally as much as the Middle, the Bottom of the Veſſel will become curved, or the Veſſel itſelf will open by ſome Chink.

APPLICATIONS.

The Woods, which we call ſoft, (becauſe being more porous than others, they are eaſier to cut) when their Surface is not dawbed over with ſome unctious Matter, become humid when they are drier than the Air that touches them. Or elſe they looſe a Part of their Moiſture, if they are placed in an Air leſs moiſt than themſelves: Becauſe it is of the Nature of Fluids, to ſpread themſelves equally every where. And as the State of the Atmoſphere is continually varying, the Woods, as well as all other ſpongious Bodies, are continually liable to Changes of Moiſtneſs and Drineſs, which makes an Alteration in their Volumes. Their Surfaces at one time encreaſe in Extent, at another time they diminiſh or contract. 'Tis for this Reaſon that Wainſcotting in new Buildings, Partitions of Deal, Cielings, and other Joiners Work, which were not made of Seaſoned Stuff, often cleave with a great Crack, and the

Joints loſe their Exactneſs and Solidity. That a Window which ſhuts eaſily at one time, becomes too large at another, and can hardly be reduced to it's Place: And that a Tub with Chinks, will ſwell in the Water and be repaired, *&c.* For, all theſe Effects are nothing elſe but an Increaſe of Dimenſion by Moiſture, or a Diminution by Drineſs.

THIS ſort of Diſorders would not be near ſo conſiderable, as they are, if this Diminution or Augmentation of the Surfaces were equal every where, and made at the ſame time. In Works that are of one Piece, or which are joined together with Glue, there would only happen a Change of Magnitude, which would be often of ſmall Conſequence. But becauſe one Side becomes moiſt and larger, while the other continues dry and without Augmentation, there will follow Flaws, Bendings, Deformities, *&c.* 'Tis thus that Wainſcot grows hollow and bunches out, when the Surface that touches a moiſt Wall, continues more extended than the other; and that a Door warps, when the Pieces that compoſe it are not equally ſuſceptible or exempt from the Impreſſions of the Air.

THE Uſe of Painting with Oil, and of Varniſhes, cures this ſort of Inconveniences very well. Thus ſtopping up the Pores of the Wood with a Matter that is not penetrable by Water, not only prevents the Moiſture from entering, but hinders that from coming out, which was incloſed at the time the Work was made. And it is a means of preſerving a conſtant State to ſuch things, which can change only by being wet or dry.

'TIS wonderful that the ſmall Parcels of Water, which inſinuate themſelves into a ſolid Matter, ſhould be able thus to augment it's Extenſion by their little but multiplied Forces, notwithſtanding thoſe vaſt Reſiſtances which ſometimes endeavour to keep it within it's Dimenſions. We have ſeen Cables made wet, with a deſign to make them ſwell, and thereby to diminiſh their Length; ſo as to draw prodigious Weights nearer to the fixed Point to which they were faſtened. An Experiment like to this, and which does not leſs deſerve our Attention, is made every Day in the Quarries, where they dig Mill-Stones, before the Eyes of thoſe who little regard the Curioſity of it. Stones of this Kind are very hard; and as they have not the Cuſtom of ſawing them, they make Choice of a Block, which is formed into the Shape of a Cylinder of a ſuitable Diameter: and while it reſts upon it's Baſis, they divide it by circular and parallel Notches, at ſuch a Diſtance from one another, as is neceſſary to make the intended Number of Mill-Stones. But as theſe Notches cannot be made deep enough to reach to the Axis of the Cylinder, there will remain a Spindle, which muſt be broken, at every Notch. To effect this, they fill theſe Notches with Wedges of ſoft and dry Wood; then they increaſe their Volume by wetting and ſprinkling Water upon them. What is to be admired in this Practice is this, that neither the Weight, nor the Hardneſs of ſuch a Stone, can hin-

Millſtones

der the Moiſture from having it's Effect upon the Wood; but by a Method ſo ſimple, and of ſo little Power in Appearance, it ſeparates the Stone from the Maſs, of which it made a Part.

EXPERIMENT II.

PREPARATION.

INSTEAD of the Glaſs Tube in the foregoing Experiment, here is put that which is repreſented by *Fig.* 2. It is furniſhed above with a Flagon of Cryſtal-Glaſs, the Bottom of which is made of Buff-Skin, and in which Quickſilver is put, to the Height of about two Fingers.

EFFECTS.

At the firſt or ſecond Stroke of the Sucker, the Mercury will paſs through the Leather, and fall ſo faſt into the Tube in little Globules, as to reſemble a Shower of Silver.

EXPLANATIONS.

THE Buff-Skin which ſerves as a Bottom to the Flagon, like the Skin of all other Animals, is very porous. The Quickſilver, which lies upon it, is not in Quantity enough to force a Paſſage by it's own Weight. But when there is joined to it the Preſſure of the external Air, as in the firſt Experiment, then it's little Globules can paſs through, and in falling can repreſent a ſilver Shower, by their Colour and Number.

APPLICATIONS.

THE Life of Animals is maintined by Food. But of all that they take in the Form of Nouriſhment, Nature makes Uſe of but a very ſmall Part, for the Subſiſtance of the Body that digeſts it. When ſhe has ſeparated her Part, and diſpoſed of it according to her Views, ſhe has Ways by which ſhe diſencumbers herſelf of the Superfluity. One would be apt to think, that the Evacuations commonly known, are thoſe which carry off the greateſt Quantity of theſe Exceedings. But there are others, which are leſs perceived, and which operate more; becauſe they are performing it continually. What is called *Tranſpiration* is nothing elſe but an Evaporation of ſuperabundant Humours, which is performed for the greater Part through the Pores of the Skin. If it is ſuch as makes the Surface of the Body notably moiſt, it is then called ſenſible Tranſpiration, or commonly *Sweating*. But this State is not natural: For, it requires violent Exerciſe, or ſome extraordinary Agitation of the inward Parts. Yet the moſt quiet Animal, and which is in the beſt Health, is not an Inſtant without tranſpiring, in a manner indeed that is hardly ſenſible, but of ſuch Efficacy in the Main, that (according to the Experiments of *Sanctorius*, of Mr *Dodart*, and of ſome other Perſons, who have made them with Care;) of eight Pounds of

Nouriſhment, which a Man may have taken in 24 Hours, inſenſible Tranſpiration has taken away five of them.

We cannot therefore be ſurprized at the Decay and Fainting of ſuch, who have been too long a Time without eating, or who take in ſuch Subſtances, as are but little capable of repairing what is continually loſt by Tranſpiration. But we have more Reaſon to be ſurprized, when we ſee lethargick Perſons, and certain Animals, as Marmoſets, Dormice, *&c.* live ſeveral Months aſleep, without taking any Nouriſhment.

Those who have ſeen living Bodies aſleep in this Manner might eaſily perceive, that their Condition much more reſembles a general Numbneſs, ſpread through the whole Habit of the Body, than any natural and common Sleep. In an Animal that is only aſleep, according to the ordinary Courſe of Nature, Reſpiration will be ſenſible and frequent. The Warmth and Softneſs of the Limbs are a Teſtimony, that the Humours are in Motion, and circulate with Freedom. There is but one Step to make, as we may ſay, from this Sleep to Awaking. Thus Tranſpiration continues; becauſe it's Cauſes are nearly the ſame. But in a lethargick Animal the Caſe is not the ſame; every thing is almoſt in an entire Inaction. It differs not from a Thing dead but by a Remainder of Motion, which is hardly to be perceived, and very often revives no more. Or, if at laſt it does revive, it's extream Leanneſs and Weakneſs, plainly ſhew what Loſs of Subſtance it has undergone by a ſlow

Tranſpiration, but of too long Continuance. I have ſometimes obſerved it in that Sort of Mice called Dormice. The State of Numbneſs in which they were, made their Limbs as ſtiff as if they had been dead. They hardly ſeemed to be warmer than the Wall from which they were taken. When there is ſcarce any Sign of internal Motion, and ſuch a Difficulty of awakening them, as to allow one to move them in any Manner, and even to hurt or wound them: In ſuch a State the Animal ſuffers but little Diſſipation, it may ſupport itſelf for ſome Time without Nouriſhment; and the Time in which it lives thus, is always that of the whole Year, wherein Tranſpiration is leſs abundant, that is, in cold Weather.

In the great Heats of Summer we tranſpire more, and commonly eat leſs, than at other Seaſons. The Parts of the Stomach, which are appointed for the Digeſtion of the Aliments, then relax themſelves, juſt at a Time when it is more neceſſary that they ſhould exerciſe their Functions. Then Animals are leſs vigorous; becauſe they loſe more, and recruit leſs, than at other Times. An Appetite to eat, and the Need of eating, are different Things.

If the Skin of Animals has Pores, which tranſmit Humours from within outwardly, it has alſo ſuch, which admit a Paſſage for Matters, which act from without to Parts within. The Art of Medicine applies Remedies outwardly, which convey their Effects to the moſt inward Parts, and will not ſuffer us to doubt of this laſt Kind of Poroſity.

EXPERIMENT III.

PREPARATION.

An Egg is put into a Glaſs Cup full of fair Water, which is covered by a Receiver upon the Plate of the Air-Pump, as is repreſented by *Fig.* 3.

EFFECTS.

When the Pump is made to work, in order to take away a Part of the Air which is within the Receiver, the whole Surface of the Egg will be covered with little Bubbles of Air, which ſeparate themſelves by little and little, to riſe to the Surface of the Water. And at certain Places of the Egg are obſerved little Spouts of Air, which are formed by a continnal Succeſſion of little Globules.

EXPLANATIONS.

The Shell of the Egg is porous, and for this Reaſon in a few Days, a Part of it's Subſtance will evaporate, which is ſoon replaced by the Air, which ſurrounds it. This Air contained in the Egg will not go out again as long as it is retained by the Preſſure of the Atmoſphere. But when this Preſſure is diminiſhed or taken away, which happens as ſoon as the Air is taken out of the Receiver, which ſqueezes the Water againſt the whole Surface of the Egg; then the internal Air, by a Property which we ſhall explain in due Time, endeavours to paſs out, and in going out ſhews the Pores of the Shell, by which it came in. Moſt of theſe Pores are ſo ſmall, that the Air cannot paſs through them but by inſenſible Parts. But the mutual Adheſion of theſe Particles retains them, till their Volume is augmented by a ſufficient Number, which forces them to ariſe to the Surface of the Air, by the Difference there is between the ſpecifick Gravity of the two Fluids.

THE Poroſity is not every where alike. There are Places where theſe little Paſſages are more open, and through which the Air paſſes freely enough, and in Quantity great enough to comply at once with it's relative Lightneſs. 'Tis that which gives Occaſion to thoſe little Spouts, which we may obſerve in ſeveral Places. The Water, which is put into the Cup, and with which the Egg ought to be quite covered, ſerves only to ſhew the Bubbles of Air, which come out of the Shell, and which could not be obſerved if they were to paſs immediately into the Air of the Receiver.

APPLICATIONS.

FRESH Eggs are thoſe which have not yet loſt that Part which is called the Milk, and which we find immediately upon opening them, when they are not boiled too hard. Thus without having Regard to their Age, one might call thoſe freſh likewiſe, which have been laid for ſeveral Days, but in which that Diſſipation of Subſtance has been prevented, which is only the Effect of the Evaporation, which is ſoon made through the Pores of the Shell. 'Tis not only a Matter of Curioſity, to preſerve Eggs freſh in Quality, which are Stale as to Age; but it is a real Advantage, always to procure one's ſelf a Food in good Condition, which often becomes doubtful when kept long. In Voyages by Sea, and at Seaſons in which Hens do not lay, or but ſeldom, 'tis a good Refuge to have a Proviſion of Eggs, which are as good as if they had been new-laid. M. *de Reaumur*, who never confines his Enquiries to Speculations of meer Curioſity, offers us a Method to do it, which ſeems to be as ſimple, and more ſure, than all thoſe which had been contrived before him. He adviſes to ſtop up the Pores of the Egg with a Covering that cannot be diſſolved by Water, and which has ſome Conſiſtance, ſo that whatever ſhall attempt to tranſpire from within to the Outſide of the Egg, cannot melt that which ſhall ſink into the Pores, being as ſo many little Corks. Two or three Coats of common Varniſh, a ſlight Covering of Mutton-Sewet, or of Wax only warmed till it is liquid, are Means which ſucceed alike. And I can ſpeak from my own Experience, that an Egg thus kept for five or ſix Months has ſtill it's Milk, and has not the leaſt offenſive Taſte.

EGGS varniſhed or covered in the Manner now ſaid, have not only the Advantage to keep good, ſo as to be eaten as if they were new-laid; they have likewiſe this Advantage, that a Hen may ſit on them with all the Safety that can be deſired, after a Time, which without this Precaution, it might be expected they would become rotten. 'Tis then a new Means to attempt to raiſe ſtrange Birds, which cannot be tranſported alive without much Trouble, and which generally do not breed out of their own Country. Their Eggs being varniſhed are eaſily brought over, will be fit to be ſat upon after a long Voyage; and we know that one Kind of Fowls will ſit upon the Eggs of another. A Hen will hatch Ducks, Pheſants, *&c.* But in ſuch a Caſe it ſhould be remembered, that Varniſhing is preferable to any other Covering, which being to be applied hot may deſtroy the Young; as alſo that the Varniſh is to be taken away, when the Eggs are to be put under the Bird that is to Hatch them. The Tranſpiration that ſhould be ſtopt till then, afterwards becomes neceſſary in the Incubation. And theſe are two Facts, which are equally aſcertained by the Trials of M. *de Reaumur*; firſt, that an Egg which is varniſhed, will continue in vain under the Bird that ſits upon it; and ſecondly, that the Egg, which has been ſo covered, and afterwards ceaſes to be ſo, may be ſat upon, and will come to Good, juſt the ſame as if it had not been covered at all.

EXPERIMENT IV.

PREPARATION.

UPON a Piece of white Paper any thing may be written or drawn, with a clear and colourleſs Liquor, which is prepared with diſtilled Vinegar and Litharge. This Paper, which will have no Sign of Writing upon it when it is dry, muſt be put within the firſt Leaves of a Book, of about four or five hundred Pages. Then upon the laſt Leaf of the Book, with a bit of Spunge, is ſpread another Liquor, which has no more Colour than the former, and which is a Preparation made with Orpiment, quick Lime, and common Water. The Book is then to be kept ſhut for about three or four Minutes. See *Fig.* 4.

EFFECTS.

WHEN the Paper is taken out which was put into the Book, that which was wrote or drawn with the firſt Liquor, will be found coloured with a darkiſh brown Colour; and in all the reſt of the Book no ſuch Marks will be found.

EXPLANATIONS.

THESE two Liquors, which Cuſtom has called *Sympathetick Inks*, are of ſuch a Nature, that wherever they meet, their Mixture appears under a Colour that neither of them had before they were joined. This is an Effect, which is common to them with many other Liquors, for which we ſhall endeavour to give a Reaſon, when we come to ſpeak of Light and Colours. The latter of theſe two Liquors exhales a very penetrating Vapour, which may be perceived by the Smell, and which paſſes through the Leaves of the Book in a very little Time. Now the Vapour of a Liquor, is the Liquor itſelf divided into very ſmall Parts; and in this State, it is equally proper to unite itſelf, with that of the firſt which was ſpread on the white Paper. Therefore a Mixture is made of both, which appears of that Colour, which they ought to produce, as often as they are joined together. And as this Colour depends abſolutely on the Union of both, the Vapour in penetrating the Book cannot leave any Trace of it's Paſſage, becauſe we ſuppoſe the Leaves had none of the firſt Liquor.

APPLICATIONS.

SINCE all occult Qualities, are baniſhed out of Natural Philoſophy, by which an Anſwer could be given to every thing, but which in Reality gave a Reaſon for nothing, to any one that deſired clear and diſtinct Ideas; we muſt no longer admit *Sympathy* and *Antipathy* as Cauſes of any Phænomenon, unleſs we take theſe Words by way of Abbreviation, for the mechanical Action of one Body upon another.

As when we ſay, ſuch a Remedy, or ſuch a Food, is good for the Breaſt, the Stomach, *&c.* A Way of ſpeaking, which is the ſame as to ſay, that a good Effect may be expected from it, without explaining at Length how this Action is performed, which is to preſerve or repair thoſe Parts of the Body. But in order to give a Reaſon of the foregoing Experiment, if any one ſhould ſay, the ſecond Liquor makes the firſt to appear, becauſe it ſympathizes with it, this would not ſatisfy thoſe who expect a rational and intelligible Explication. It would be required of him to ſhew particularly, or at leaſt in general, in what this Sympathy conſiſts. His Reaſons would not be admitted, unleſs he could derive them from known Principles. For, in his Rationale, if he ſhould introduce any thing new in Phyſicks, he would ſtill be put upon the Proof of it; without which it would all be only an Hypotheſis; and therefore of no Force.

THAT which makes them have Recourſe to Sympathies and Antipathies, to explain certain Facts, is generally the Difficulty they find to reconcile them with the known and ordinary Laws of Nature. But thoſe who do this, are often but little acquainted with theſe Laws, or with the Uſe that may be made of the Knowledge of them. A Man well furniſhed with this Knowledge knows alſo, that the Properties of Bodies already known are few in Number, but that they are very fruitful in their Applications. They ſhew themſelves ſo many different Ways, that he can hardly perſwade himſelf he ſhall ever find them to fail him Without flattering himſelf that he knows them all, he hardly allows himſelf the Liberty of imagining new ones. He rather chooſes to believe, that he does not ſee them always where they really are, and that what he cannot now perceive, may poſſibly be reſerved for ſome happier Genius.

BUT it muſt be confeſſed, that Facts are often inexplicable, becauſe they are either falſe or miſrepreſented; and if we would act prudently, they ſhould be well verified before we are at the Trouble of making an Explication of them. Thoſe that relate them to us, have believed they ſaw what they really did not ſee; for want of Diſcernment or Attention. Or, perhaps they repeat them after Perſons, that have ſome Intereſt in them, or Men of no Veracity. If Credulity, and the Affectation of telling ſomething marvellous, come likewiſe to the Aſſiſtance of Ignorance and Prepoſſeſſion; we may receive, as undoubted Facts, all the ſhallow and puerile Imaginations that offer, and all the Exaggerations that paſs from Mouth to Mouth, which gain Credit by Time, and by the Authority of ſomebody, who was ſuppoſed to have more Knowledge than he really had. I am not now ſpeaking of the ſuppoſed Impoſſibility of tuning a Muſical Inſtrument of two Strings, one of which is made of the Gutts of a Sheep, and the other of the Gutts of a Wolf: Or, of the imagined Danger of caſting into the Fire, either Urine or Blood: Or, of a Cure, which is to be performed by carrying certain Fruits in one's Pocket, or by throwing them into a Well: Or, of infinite other like Remedies, or Preſervatives, which every one now knows to be ridiculous, and which are ſupported by no philoſophical Experiments. How long did the World ſtand amazed at the famous Sympathetick Powder, and it's wonderful Effects? Yet 'tis known to be nothing elſe but Vitriol calcined by the Sun, and made into a Powder. This Mineral is aſtringent, and when it is applied to a Wound, it will hardly fail to dry it up, and to diſpoſe it to cloſe in a ſhort time. Hitherto there is no Sympathy, in the Senſe this Word is taken. Alſo when this Powder is made Uſe of near the wounded Perſon, upon a Cloth dipt in his Blood ſtill warm, it ſometimes happens that the Wound feels it, or is ſenſible of it: There is yet nothing ſympathetick, but to thoſe that are ignorant, that Vitriol pulverized exhales into inſenſible Particles, which the ambient Air carries about, and which joins itſelf to humid things preferably to others. But the Marvel of this Operation is, when this Powder acts at a great Diſtance, as from four to ſix or ten Leagues.

There is no Probability, it muſt be owned, of ever explaining ſuch a Phænomenon with any Appearance of Truth, according to the known and ordinary Laws of Nature: And in vain ſhould we attempt to explain it, if it be nothing elſe but the extravagant boaſting of ſome Quack, blindly ſupported by Credulity, and by a fond Deſire of hearing and telling Miracles. But this is the Sentiment we ought to have of it, according to the Opinion of thoſe*, who would truſt nothing but their own Eyes in this Matter. How many ſuch like Chimeras would vaniſh into nothing, if only Facts were faithfully related, with all their concomitant Circumſtances?

NOTWITHSTANDING we are certain, that Poroſity is a Property common to all Bodies; yet we do not know the abſolute Quantity of theſe Pores. For, as all Matter is heavy, and as Gravity belongs only to what is material, we know very well, that one Body has leſs Vacuum than another, when, Volumes being equal, it weighs more than the other. But this Compariſon ſhews only their relative Poroſity. It does not tell us, that in one of the two there is juſt ſuch or ſuch a Quantity of ſolid Parts, which would teach us very ſatisfactorily how porous it is. The true Means of being informed of this would be, to have a Standard of Compariſon, which ſhould be entirely ſolid, in which the Magnitude and the Weight would be truly ſynonymous. For in comparing a Portion of this Matter with an equal Volume of another Matter, if this, for Example, ſhould weigh leſs by half, we ſhould have Reaſon to conclude, not only that it is leſs ſolid by half, as we generally do, but we ſhould alſo know the juſt value of this *leſs*. And we ſhould look upon it as a Thing certain, that the Poroſity of this compared Matter was equal to it's Solidity. Becauſe the Gravity, which is an Attribute inſeparable from all Parts of Matter, would be there perceived to be but half as much, as in an equal Bulk which is nothing but Matter.

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* *Lemery's* Courſe of Chymiſtry, p. 492.

BUT a Body of this Kind will never be any thing elſe but a meer Suppoſition, which can never become real. For, we know no ſuch Body in all Nature. Of all Material Beings, that we are acquainted with, Gold is the moſt compact, and contains moſt Matter under a determinate Magnitude. There is no known Matter, of which a cubical Inch weighs ſo much as a cubical Inch of Gold. Yet this Metal is porous, becauſe Quickſilver penetrates into it in a Moment; and *Aqua Regia*, which is made Uſe of to diſſolve it, acts from Surface to Surface, even to the laſt. Several Philoſophers* have even carried their Conjectures ſo far as to believe, that in Gold there may be as much *Vacuum* as *Plenum*. What Notion muſt we have then of the Poroſity of other Bodies? Of common Water, for Example, which weighs about 19 Times leſs than Gold; or of Air, which is 800 Times leſs ſolid than Water?

ONE Matter is not always more porous than another, for this Reaſon only, becauſe it's Pores are more open. Often the Number makes amends for, or even exceeds in one, what the Greatneſs of the Pores does in another. However a Cork may be compreſſed in the Neck of a Bottle, yet it never becomes as compact as a Piece of Wood of any other Kind. As for Example: Tho' it's Volume may be diminſhed by Compreſſion, it can never be made as heavy as Oak: It's Poroſity then is always greater, yet neither Oak, nor any other Wood will ever be ſo convenient as Cork, to prevent the Evaporation of any Liquor incloſed in a Veſſel. It is therefore more than probable, that if in one of the two the Sum of the Vacuities is greater, 'tis not ſo much on account of the Greatneſs as the Number of the Pores. When *Aqua Regia*, which diſſolves Gold, refuſes to penetrate a Maſs of Silver; Will any one ſay, in conſequence of the relative Lightneſs of this Metal, that it has it's Pores more open than the firſt? That which enters into this, why cannot it ſubdue the other, if, as is ſuppoſed, it's Parts being more diſtant from one another, give a better Opportunity to the Diſſolvent? Would it not be better to ſay, that the little Vacuities in the Silver are not altogether ſo great as in the Gold, but that they are much more numerous?

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* *Newton's* Treatiſe of Opticks, l. ii. p. 3. prop. 8.

HITHERTO the Explanation does not ſucceed amiſs. But if it is anſwered, that the common *Aqua Fortis* that divides ſilver, and the greateſt Part of other Metals, does not touch Gold; it muſt be owned, that the relative Magnitude of the Pores, becomes but a weak Reaſon. For, why cannot that, which inſinuates itſelf into a leſs Aperture, do the ſame into a greater? Is it becauſe there muſt be an exact Proportion between the little Points of the Diſſolvent, and the Pores of the Matter to be diſſolved? Or to ſupport this Explication, muſt Figure be annexed to Magnitude?

We cannot doubt but that one Matter differs from another by the Configuration of it's inſenſible Parts; and becauſe they are differently figured in different Bodies, it follows, that the Pores in every one muſt be of different Forms. By the help of this Principle, which is inconteſtable, we may eaſily conceive, that a ſolid Particle, muſt not only have a ſuitable Magnitude, but alſo a convenient Figure, in order to place itſelf in one of theſe little Vacancies, or to paſs from one to another. And that if one of theſe two Conditions ſhould fail, the other may eaſily be inſufficient. This is a Caſe in which we are obliged to acknowledge, that even with ſure Principles, and which are granted in other reſpects, we muſt ſtill continue in Doubt as to our Explications, when we apply theſe Principles only upon Conjecture, and that Experiment does not declare whether we have gueſſed right or no.

But finally, tho' we ſhould be ignorant whether it is a Proportion of Magnitude or of Figure, or both together, which makes a Diſſolvent to act upon one Matter preferably to another; the Fact is not the leſs known for that, and the Arts for a long time have converted it to Uſe.

The Etcher takes a Plate of Copper, which is thin and well poliſhed; he daubs it over ſlightly with a Covering of a Kind of prepared Wax, which he blackens over with the Smoak of a Lamp. He draws upon this covered Surface with a Steel Point, which lays open the Copper by as many Strokes as his Deſign requires. He borders his Plate with a

Ridge of ſoft Wax, he places it in a Horizontal Poſition, and covers it three or four Lines deep with *Aqua Fortis*, weakened with common Water a third Part or one Half. In a little time the Copper, that was diſcovered by the Steel Point, yields to the Action of the Diſſolvent, and is eaten away more or leſs according to the Intention of the Artiſt, who regulates the Continuance of the Operation. In the mean while the Wax, which is not at all diſſolved by the *Aqua Fortis*, preſerves the reſt of the Surface from receiving any Injury. 'Tis thus they prepare a Leaf of Metal, in order to multiply the ſame Stamp three or four thouſand times, by making it paſs ſucceſſively through the Preſs, upon ſo many Leaves of Paper.

MARBLE is impenetrable to Water, and many other Liquors. But it is not ſo to Spirit of Wine, Spirit of Turpentine, or melted Wax. Theſe Exceptions have been applied by ingenious Perſons, as ſo many means for introducing foreign Colours into the inſide of Marble, and to make white Marble imitate other Kinds, which are naturally coloured. The late Mr *Dufay*, who was very expert in tinging hard Stones, and who has communicated his Diſcoveries of this Kind, to the Academy of Sciences [*], has often ſhewed me Tables of Marble artificially tinged, which were well imitated, and ſo ſtrongly penetrated, that they were afterwards poliſhed, without loſing any thing of their Colours.

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[*] Memoirs of the Academy for 1728. p. 50.

The Verniſhes of which now ſo much Uſe is made, are nothing elſe but Gums of different Sorts, which are liquified by Means of ſome Diſſolvent. Such a one diſſolves in Spirit of Wine, which continues whole in Oils; and theſe Oils are employed ſucceſsfully in the melting of others. The whole Art conſiſts in knowing in what Menſtruum each is diſſolvable; and this Choice without Doubt becomes neceſſary, only upon account of the Difference there is, between the Poroſity of one and that of another.

SECTION III.

Of the COMPRESSIBILITY *and the* ELASTICITY *of* BODIES.

WHAT we have already ſaid of Poroſity muſt make it evident, that the apparent Magnitude of any Body muſt always exceed the real Quantity of it's own Matter. And this Exceſs perhaps is as various, as are the Kinds of Bodies that compoſe the Univerſe. For we ſeldom find two Sorts of Matter, which weigh equally under equal Volumes.

THIS Relation of the Volume to the Maſs is what we call *Denſity.* One Body is more denſe than another, when the real Quantity of it's Matter differs leſs from it's apparent Magnitude; or, which is the ſame thing, when under a given Magnitude it contains more ſolid Parts. Therefore Lead is more denſe than Copper: But Air is not ſo denſe as Water.

BUT the ſame Body may change it's Denſity. That is to ſay, it's Maſs continuing the ſame, it's Volume may vary either by increaſing or diminiſhing. When a Body becomes more denſe, 'tis becauſe it's ſolid Parts contract themſelves cloſer into a leſs Space; and this may be done two ways, either by removing an internal Cauſe, that kept the Parts at a greater Diſtance, or when we apply a Force externally, which obliges them to approach nearer to one another. We may diſtinguiſh from one another, each of theſe two ways of diminiſhing the Volume of a Body, by calling the firſt *Condenſation*, the other *Compreſſion*. (Tho' to ſpeak ſtrictly, it will always be *condenſing* a Matter, when we create a Diminution of it's Volume, let the way of doing it be what it will.) Thus to ſqueeze Snow in our hands to make a Ball of it, is to compreſs it; to cool a Liquor, or to diminiſh the Heat that dilated it's Parts, is to condenſe it.

We know no Body in Nature, (abſtracting from the Elementary Particles, or Atoms, if there be any ſuch,) the Volume of which may not be diminiſhed by one of theſe two ways, and often by both. How hard ſoever a Matter may be, it is never perfectly ſo; it's Particles are always more or leſs dilated, either by an internal Motion, which may be abated, or by the Action of ſome foreign Fluid, which penetrates it, which may be overcome by an external Power. For Example; a Bar of Iron, which has been made red hot, afterwards becomes ſmaller and harder as it grows cold; becauſe it's Parts by little and little, approach nearer to one another, by loſing the violent Motion that they had acquired in the Fire. A

Sponge ſoaked and dilated by the Water it contains, is reduced to a much leſs Space, when the Water that fills it's Pores, is ſqueezed out. A Ball of Marble or of Glaſs, even a Diamond itſelf, when thrown againſt any thing that is very hard, will rebound at that very Inſtant; and we ſhall ſhew preſently, that the Motion of Reflexion is a Proof of the Compreſſibility of the Body reflected.

All Bodies in general, whatever State they are in, Solid, Fluid, or Liquid, are ſuſceptible of Condenſation. A Piece of Marble, eſpecially if Black, is found to be ſenſibly leſs, when it has continued for ſome time in a Place, much colder than where it was before, when it was firſt meaſured. A Bladder or Foot-Ball filled with Air in the Summer time, becomes flabby in the Winter. And the Liquor of the Thermometer does not deſcend towards the Ball, but when it's Volume is no longer ſufficient to fill the Part of the Tube, which it poſſeſſed when the Weather was hotter. But we ſhall forbear to ſpeak more at large of the Manner in which Bodies are condenſed, till we come to treat of the Fire and Heat, by which they are rarified.

As to Compreſſion, we cannot ſay that it belongs ſo generally to Matter conſidered in all it's States. All ſolid Bodies are compreſſible, and Experience hitherto has not excepted one. Air may be conſiderably compreſſed, and by this Property it exhibits ſurprizing Effects, which we ſhall relate in due Place. Other Fluids, as Smoak, Flame, *&c.* have never yet been tried in this View; becauſe, without Doubt, it would be very difficult, and perhaps impoſſible, to apply them alone to Experiments of this Kind. But as to Liquors, they have never given directly any token of Compreſſibility, whatever Attempts have been made. And it ſeems as if all was done at firſt that could be done. The Experiment of the Academy *del Cimento* was as ingenious as the Reſult was little expected. And it does not appear, that any other have ſince tried it to better Purpoſe. Sir *I. Newton*[*] relates it as a very curious thing; and as if he had apprehended, that ſo ſurprizing an Effect ſhould be received without Heſitation; he aſſures us that he received it from an Eye-witneſs. As to myſelf, I can appeal to my own Eyes for the Truth of it, and the Uſe I make of it in my Courſes, has already put it in the Power of many Perſons to do the ſame. This is the Fact.

EXPERIMENT I.

PREPARATION.

A BALL of Metal, the Capacity of which was exeactly meaſured, and which was thin enough to be flexible, was entirely filled with Water, and ſtopped up in ſuch Manner as that none could be loſt at the Orifice; it was applied to a little Preſs, as is repreſented at *Fig.* 5.

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[*] Treatiſe of *Opticks*, l. 2. Part 3. Prop. 8.

EFFECTS

EFFECTS.

WHEN the Preſs was made to act upon it, the Ball of Metal being compreſſed, became a little flat; and as we went on to preſs it, the Water made it's way through the Pores, and appeared upon the Surface in little Drops like thoſe of Dew.

EXPLANATIONS.

IT is a Matter of Demonſtration, that a Spherical Capacity, when the Surfaces are equal, includes more Matter than any other. It follows then, that if a Veſſel of this Figure be full; it cannot loſe it, but one of theſe two things muſt happen. Either it muſt increaſe in Surface to preſerve the ſame Capacity, or what it contains, muſt be condenſed by diminiſhing it's Volume. When the Water begins to paſs through the Metal, the Ball is found to be a little flattened; but meaſuring it's Capacity, we find it to be the ſame as before the Experiment began: We muſt therefore conclude, that this flattening is owing only to the Ductility of the Metal, and that the Volume of the Water was not ſenſibly diminiſhed under the Preſs.

LORD *Bacon*, Mr *Boyle*, and ſome other Philoſophers, having attempted to compreſs Water in Boxes of Metal, have thought they found Marks of it's Compreſſibility; but it is very likely that what they perceived, was owing to the Flexibility or Elaſticity of the Metal, or elſe to that of ſome Bubbles of Air, which were incloſed in the Box with the Water.

EXPERIMENT II.

PREPARATION.

IN *Fig*. 6. ABCD is a very thick Glaſs Tube, which is three Lines Diameter within, is ſeven Feet high, and is crooked at the End, like a Hook. At firſt a little Quickſilver is poured in, which fills the Curvature, and which comes to a Level at BC. The Part CD is filled with Water, the Tub is ſtopt perfectly and ſubſtantially at D, and then Quickſilver is poured into the Branch AB, till it is compleatly full.

EFFECTS.

THE Column of Water, which is between C and D, oppoſes the Preſſure of the Quickſilver with ſo much Reſiſtance, that it does not ſenſibly diminiſh in Volume.

EXPLANATIONS.

WE ſhall make it appear, when we come to treat of *Hydroſtaticks*, that the Preſſure exerted by the Mercury againſt the Water in C, is equal to the Weight of the Column contained in the Part AB of the Tube. But this Column of Mercury, which is about 6 Feet 10 Inches high, is equal to three times the Weight of the Atmoſphere, which riſes to a very great Force. And ſince it is not ſufficient to condenſe ſenſibly the Volume of Water, againſt which it acts; 'tis a Proof, that the Parts of Liquids are very hard, and that the Subſtances in this State, are but little flexible.

APPLICATIONS.

ALTHOUGH in the Experiments we have now produced, the Water gave no perceivable token of Condenſation; yet we muſt not conclude from thence, that Liquors are abſolutely incompreſſible, but only that they are able to reſiſt all the Attempts that have hitherto been made to compreſs them. Every thing inclines us to believe, that at laſt they would yield in a ſenſible Manner, if it was poſſible to expoſe them to greater Degrees of Preſſure; and that they yield even to thoſe we now make Uſe of, but in a Quantity which is too little to be perceived. All ſolid Bodies are compreſſible, becauſe they are porous, and therefore their Parts may approach nearer to one another. And what elſe is a Liquor, but a Collection of little ſolid Bodies, which we may conſider as ſimple Subſtances, or rather as little Maſſes compoſed of Parts, which are not ſo cloſely united, but that they leave little Vacuities between them. If Poroſity makes the greater Bodies capable of Condenſation, Ought not the ſame Cauſe to produce the ſame Effect in ſmaller Bodies? All that can be ſaid is, that Compreſſibility ought to diminiſh with the Magnitude of the Bodies; that is to ſay, that the leaſt are leſs flexible; that conſequently the Parts of one Liquor, becauſe of their extream Smallneſs, are Proof againſt the greateſt Force. But it follows from the ſame Principle, that none are abſolutely incompreſſible, but what are abſolutely ſimple; ſuch as Atoms would be, or the primary Parts of Bodies, upon which our Experiments can take no hold.

It is for our Advantage, that whatever is liquid can reſiſt ſuch Preſſures, as would batter and bruiſe other Bodies. Whatever we draw from Vegetables by Expreſſion, as Wine, Cyder, Oils, *&c.* would never ſeparate from the ſolid Parts that contain them, if the Liquids could be compreſſed as well as the Solids. Fruits committed to the Preſs, would only change their Volume. The Eaſineſs that we find in extracting the Juices, which Nature has there prepared for our Uſe, is almoſt wholly owing to the Reſiſtance, that Liquids oppoſe to being compreſſed.

We cannot but be ſurprized when we conſider, that the ſame Body is compreſſible or not, according as a greater or leſſer Degree of Heat changes it's Condition. A Piece of Ice exhibits Marks of Compreſſion. Let it be reduced to Water, and it is ſtill the ſame Matter, but is no longer compreſſible. Wax, Sulphur, Metal, *&c.* ſhew the ſame thing, when they are made to paſs from a State of Solidity to that of Liquidity. This Phænomenon is of ſome conſequence, and deſerves well to be explained. But the Misfortune is, we can only offer a Conjecture; yet it is a Conjecture founded upon known Principles, which makes it very probable.

WE may affirm, that the natural State of almoſt all Bodies is to be ſolid. When they become Liquids 'tis becauſe a foreign Matter makes them ſuch, by penetrating their inward Parts, and either by their Quantity or Action, by giving a relative Motion to thoſe Parts, which breaks all their Connexion, and almoſt all their Adheſion to one another. 'Tis thus that Clay, ſoaked with a ſufficient Quantity of Water, becomes a Mud, which runs upon an inclined Plain. Water itſelf ceaſes to be Ice, as ſoon as a more ſubtile Fluid, known by the Name of the *Matter of Fire*, penetrates it in a ſufficient Quantity, and gives it Motion enough to looſen it's Parts from one another.

Now if a Reaſon ſhould be aſked, why ſolid Bodies may be compreſſed, and Liquors have not the ſame Property? May it not be anſwered with ſome Probability, that in the firſt the Parts ſtand upon an uncertain Foundation, or are only ſupported by a Fluid without Action, which gives way at the leaſt Shock; whereas in Liquors, the Particles being more divided, and for this Reaſon being already leſs flexible, are ſupported by a Fluid in more Abundance, the Parts of which are ſo much the harder as they are more ſimple. If we ſhould put into a Veſſel, a certain Quantity of little Balls of Steel, or of any other Matter of equal Hardneſs, they would not ſenſibly yield to Compreſſion, whether they were alone, provided they touch, or whether they were mingled with others that are ſmaller, which would hinder them from touching; ſuppoſing that theſe laſt were themſelves inflexible. See *Fig.* 8.

EXPERIMENT III.

PREPARATION.

UPON a Table of black Marble which is very ſmooth, and ſmeared lightly over with Oil; from the Height of two or three Feet, at ſeveral times, and in different Places, is let fall a little Ball of Ivory, which may be about three Quarters of an Inch in Diameter. See *Fig.* 7.

EFFECTS.

BY looking obliquely upon the Marble Table, wherever the Ivory Ball has touched it, we ſhall perceive a round Speck, about two Lines in Diameter; which Speck will be greater in thoſe Places where the Ball has fallen higher.

EXPLANATIONS.

IVORY, tho' very hard and firm, yet is a compreſſible Matter. When it falls upon the Marble, the Motion of it's Weight, which urges it, occaſions a Preſſure, which puſhes a greater or leſs Part of this little Sphere towards it's Centre. And as theſe compreſſed Parts are of a Nature to reſtore themſelves again in an Inſtant, there remains no Mark of this Compreſſion upon the Ball, but the Speck which appears upon the Marble, is an inconteſtable Proof of that flattening, which now diſappears. If we ſhould chooſe rather to ſay, that the Marble ſunk down and reſtored itſelf immediately; this equally proves the Compreſſibility of a very hard Body. Probably both of them happen; the ſame Compreſſion may pit the Marble, and flatten the Ball. But of theſe two Effects, the latter is doubtleſs the moſt conſiderable, whereby to judge of the Nature of theſe two compreſſed Bodies. Wherefore we ſhall adhere to the latter by way of Preference, and what we ſhall now ſhew, that the round Speck inconteſtably proves the flattening of the Ball, abſtracting from the Flexibility of the Marble, would likewiſe oblige us to admit the pitting or ſinking of the Marble, if we had no Regard to the Compreſſibility of the Ivory.

'Tis known that the Circumference of a Circle, when it's Convexity is applied to a Right-Line, touches it but in one Point G, *Fig.* 9. 'Tis conceived alſo, that ſpherical Surfaces are compoſed of circular Lines, as Plains are of right Lines, and that the Surfaces have the ſame Reſpect to one another as the Lines, that compoſe them have; if the Circle touches the right Line but in one Point, the Ivory

Ball in our Experiment, if only ſet down upon the MarbleTable, would touch it likewiſe but in one Point. When it was let fall, if it appears that it applied itſelf to the Marble according to a circular Surface of two Lines in Diameter, we muſt neceſſarily allow, that the firſt Point of touching, *g*, *Fig*. 9. has approached nearer to the Centre by the Force of Compreſſion, and that after this, the Points round about have ſuffered the ſame diſplacing: This has given way for a ſenſible Portion of the Surface to apply itſelf to the Marble, and to leave an Impreſſion there upon the ſlight Coat of Oil, with which it was covered.

APPLICATIONS.

IF a Body is compreſſed equally through the whole Extent of it's Surface, provided it be compreſſible, nothing can follow but a Diminution of it's Volume; becauſe all the oppoſite Points ſubmit to equal Powers, and their reſpective Situations continue the ſame. Such is the State of an Animal that lives in the Air or in the Water: Being ſurrounded on all Sides by one of theſe two Fluids, they are not ſenſible of their Preſſure, tho' it be conſiderable; becauſe it makes an Equilibrium with itſelf, and diſplaces nothing of that, which is expoſed to it's Force. But if the Compreſſion ſhould be greater on one Side than on the other, it's Effect would be no longer confined to diminiſh the Volume; the Figure alſo would be changed, as may be perceived by the Fall of a Ball of Lead upon a hard Body, which then would looſe a Part of it's Sphericity: Or, by throwing a Hand-Ball againſt a Wall, which often leaves remarkable Footſteps of it's flattening.

Of the Elaſticity, or Springineſs of BODIES.

Of all Bodies, that are compreſſed, ſome continue in the State that the Compreſſion has made them aſſume; that is to ſay, they, that have changed either Magnitude or Figure, remain in this Change, even when their Compreſſion is over: As the Ball of Lead, which continues flattened after the Fall; and a Snow-Ball, which remains in the Form, which has been given by the Hands, that ſqueezed it up. Others, on the contrary, reſtore themſelves, and, after having been compreſſed, they re-aſſume the ſame Dimenſions, and the ſame Figure, which they had before. Such is the Ball of Ivory of the foregoing Experiment; and ſuch is a Bubble of Air, which riſing from the Bottom of a Veſſel full of Water, becomes greater, as it riſes higher towards the Surface.

Bodies of this laſt Kind, are called *Elaſtic*, or *Springy* Bodies. For *Elaſticity* is nothing elſe but that Endeavour, by which certain compreſſed Bodies ſtrive to reſtore themſelves to their natural State. This Property therefore ſuppoſes that they are compreſſible; and as Liquors are not ſo in any ſenſible Manner, we are to conclude, that if they have any

Springineſs, their Re-action has too little Extent to be viſible.

LIKEWISE all the Bodies that are elaſtic, are not ſo in the ſame Degree. Some of them hardly reſtore themſelves at all, and then, as to Uſe, their Elaſticity is looked upon as none at all. This Kind of Bodies are called *Soft*, which means only a Privation of Springineſs, ſuch as is active enough to be conſidered.

THOSE in which the Elaſtic Force may be perceived, re-act more or leſs according to the Hardneſs, Stifneſs, or Diſpoſition of their internal Parts. But there are none, of which we may aſſure ourſelves by poſitive Proofs, that their Elaſticity is perfect and unalterable. We almoſt always obſerve, that this Quality may be loſt or weakened by long Exerciſe, or by a Compreſſion of too long Continuance. A Bow, which is too often bent, or for too long a Time, keeps at laſt the Curvature, which has been given it. Hair, Wool, or Feathers, with which Houſhold-Furniture is ſtuffed, in Proceſs of Time, looſe almoſt all the Conveniance they afforded when new; and their ſinking down, is the neceſſary Conſequence of a Springineſs worn out.

WE muſt not therefore promiſe ourſelves Experiments, that are rigorouſly exact, to eſtabliſh the Theory of Elaſticity; ſince the Bodies, which have the moſt of it have not yet enough, or ſo much as is neceſſary, to render them perfectly elaſtic. Beſides, we cannot operate but in ſome material Medium: Tho' we ſhould chooſe the Air, which is the leaſt ſo, we have already ſhewn, that it is capable of Reſiſtance, and we ought to expect, that it will deſtroy ſome Part of the Effect, tho' ever ſo little. But near Approaches are ſufficient, when there is wanting but very little of Exactneſs, and when we are obliged to make Abatements for inevitable Obſtacles. Tempered Steel, and Ivory, have appeared to me as proper enough for the Effects, by which we are to prove what is moſt needful to know about Elaſticity. Therefore I ſhall make uſe of them preferably to any other Matter, in Experiments of this Kind. But as thoſe, which I have made choice of, require ſome Knowledge of the principal Properties of Motion, of which as yet we have ſaid nothing; I thought it beſt to omit them at preſent, and ſo much the rather, becauſe they will find a proper Place hereafter among thoſe, which we ſhall make uſe of to ſhew the Laws of Motion in the Percuſſion of Bodies.

THE Arts have employed Elaſticity, to ſo many good Purpoſes, that it would be a long and needleſs Undertaking to enumerate them here. It will be enough to produce an Example or two, by which we may judge of the Uſefulneſs of others.

IF it is uſeful and convenient to travel at ones eaſe; almoſt all this Advantage, is owing to thoſe Plates of Steel, to the Straps of Leather, and to other elaſtic Bodies, upon which Coaches and Chariots are ſuſpended. Without this Precaution, the beſt Poſt-Chaiſe, or the fineſt Coach, would be nothing better than a Tumbril or Dung-Cart covered and adorned, in which one ſhould be miſerably jolted: For, if all that compoſes the Carriage, were equally inflexible, the Diverſity of Motions created, and ſuddenly interrupted by the Roughneſs of the Roads, would be communicated with all their Violence to the Perſons riding within.

THE Meaſuring of Time, is a thing of ſo much concern to every Body, that there are few without a Pendulum-Clock, or a Watch, and who do not look upon it as a neceſſary Piece of Furniture. This Kind of Inſtruments, which are to be conſidered as a Maſter-piece of Art, are put in Motion by a Spring, (*Fig.* 10.) formed of a Plate of Steel, rolled up within itſelf, and lying in a little Barrel, which it makes to turn as it unfolds itſelf, the Motion of which is communicated by indented Wheels, quite to the Pivots or Axis, which carry the Hands; which Hands are thereby made to ſhew the Hours and Minutes upon a Dial-Plate divided for this Purpoſe. We ſhall mention elſewhere, how they have arrived to the Art of making the Action of the Spring to be nearly equal, during the whole Time that it unwinds. For, there is a Difficulty that preſents itſelf at firſt Sight; which is, that this Action continually diminiſhing, as the Spring unbends, the Motion muſt alſo retard in all the Pieces that are governed by it, and ſo the Hands would make the Hours, and the Minutes, longer towards the End than at the Beginning. Therefore a Remedy was to be found to this Inconvenience, which they have accompliſhed by a very ingenious Device, of which we ſhall have Occaſion to ſpeak when we treat of the Theory of the Leaver, and of the Machines relating thereto.

Of what Aſſiſtance are Springs in the Buſineſs of Gunnery? By what other Means could ſuch quick Motions be procured, and ſo hard to be perceived by a Bird, or by a Quadruped, which Nature has taught to be upon the watch againſt every thing that threatens it's Life; and which defeats the Craft and Dextery of the ableſt Sportſman, by Organs of an exquiſite Senſe, and by an Agility, which often defies his Purſuits? The Trigger of a Gun, directed by a Spring, ſtrikes in an Inſtant, a ſharp Flint againſt a little Piece of tempered Steel. The Fire catches the Powder, and the Bullet, driven by it, ſmites the Animal, before it has had any warning, either by the Flame or the Sound; or at leaſt before it can make any Advantage of that Warning.

Not only the Arts have made good Uſe of the Elaſticity of Bodies, and have made commodious Applications of it; but they have alſo found Means producing it, or of increaſing it, in ſuch Bodies as have little or nothing of it.

All ſonorous Bodies muſt be ſpringy, as we ſhall prove more at large after our Experiments upon the Air. 'Tis for this Reaſon, that they make Bells with Copper and Pewter melted together. For it has been obſerved, that mixed Metal is harder, and ſtiffer, and more elaſtic, than the ſimple Metals of which it is compoſed.

The Generality of Metals, even without Allay, become capable of a greater Re-action when they are hammered cold: This the Workmen call *Caſe-hardening*. This is eaſily perceived by the Veſſel itſelf. when a Spoon, or Fork, has only been caſt and filed, and owes nothing to the Hammer, the Faſhion of it is not ſo dear; but then it is leſs durable: The Piece is cracked with the leaſt Violence, and it's Poliſh is never ſo neat. A Workman ſkilled in Clock-Work, in Mathematical Inſtruments, in Goldſmiths Work, *&c.* never fails to caſe-harden his Work, not only to give it more Solidity, but alſo to make it more valuable by a more ſhining Poliſh, in bringing the Particles nearer together, and making the Pores of the Metal more cloſe.

A Miſtake, this is called Hammer-hardening
Caſe=hardening is done quite otherwiſe

But of all the Bodies, of which the Springineſs is increaſed by Art, there is none more remarkable than Iron converted into Steel; and among the different Proceſſes made uſe of for this Purpoſe upon this Metal, nothing is comparable to *Tempering*.

Here I muſt inform you, *firſt*, that Steel is not a particular Metal; it ſhould be conſidered as Iron prepared; and tho' there are Mines that ſupply it immediately, the moſt common and the fineſt, is that which is made with forged Iron, by introducing into it, a certain Quantity of ſaline and ſulphurious Parts, which increaſe it's Hardneſs, and make it fit to be tempered. *Secondly*, to temper Steel, is to cool it ſuddenly, the very Moment it is taken red-hot out of the Fire; and this is commonly done by plunging it into cold Water, or into ſome ſuch like thing.

THE chief Effects that reſult from the Tempering of Steel, and from which the Arts receive the greateſt Advantage, are to render it very hard; to increaſe it's Elaſticity, and to make it durable. All ſharp and cutting Tools, even to thoſe made Uſe of for cultivating the Earth; in a Word, from the Lancet down to the Spade; all owe their principal Merit to this Hardneſs, which coſts ſo little, and which would be hurtful, if carried to Exceſs; if they did not take care to moderate it by a Degree of Heat, which comes after Tempering, and which they call Softening or *Annealing*.

THE admirable Effects of giving Steel this Temper, have juſtly raiſed the Curioſity of the moſt able Philoſophers. All of them have wiſhed to know the Cauſes of it, and ſome have ventured to explain them. But it muſt be allowed, that no Body has given ſo probable an Account of this Matter, and ſo well ſupported, as M. *de Reaumur*. After a Series of Experiments of many Years Continuance, he ſuppoſes that the Action of the Fire, drives out of the Middle of the Particles of the Steel, a great Part of thoſe Salts and Sulphurs, which are there concealed; yet without making them totally to forſake the Maſs. Which Suppoſition is founded upon the common and known Effects of Fire, and upon Experience. For, we know by other Means, that in the melting of heterogeneous and fixed Matters, the Fire always cauſes a Union of like Parts. And when it's Action is increaſed to a certain Point upon the Steel, it robs it of it's Sulphurs and it's Salts, which Workmen call *burning* it. The tempering then takes hold of the Steel, at a Time when it's Principles, tho' the ſame, are found differently mixed together. Before it is hot, the ſaline, ſulphureous, metallick, *&c.* Parts, being extreamly comminuated, and intimately mixed together, compoſed a Whole of a more uniform Contexture, but yet more heterogeneous, as to it's Particles; becauſe every one equally pertook of three or four Sorts of Matters, which enter into the Compoſition of Steel. But after a ſufficient Degree of Fire the Salts, and the Sulphurs, being extracted and rolled up, as we may ſay, ſeparate from the metallick Parts, make a Whole which is more homogeneous, as to it's Particles; but more porous and leſs connected, as to the Aſſemblage of theſe little Pellets of different Kinds. This Hypotheſis, if to be called one, explains very happily all the Phænomena belonging to the tempering of Steel. For,

1. STEEL, when broke, appears to be of a coarſer Grain after it has been tempered; becauſe the little metallick Parts, which are the more apparent, on account of their Colour, are collected into little Maſſes, more at a Diſtance from one another.

2. THE Temper gives more Volume to the Steel than it had before. And this ſhould be ſo; becauſe it fixes it in ſuch a State, wherein the Mixture and the Union of it's Principles are leſs.

3. THE Steel hardens by being tempered; becauſe it's Particles are formed of more ſimilar Parts, and for this Reaſon more capable of uniting.

4. HARDENED Steel, breaks ſooner than that which is not hardened, or is leſs hardened; becauſe the Adheſion of it's Particles between one another is leſs, ſince they are of unlike Matters, and touch one another by ſmaller Surfaces.

5. LASTLY, Softening makes tempered Steel leſs brittle and more flexible; becauſe a moderate Degree of Fire, partly produces an intimate Mixture of unlike Parts, and makes it take a middle State, between that of Steel not tempered, and Steel tempered to Exceſs.

ALTHO' we have Proceſſes that are certain for increaſing, diminiſhing, and taking away the Springineſs of ſeveral Bodies; yet for all that we do not know any better the Cauſes of Elaſticity in general. Whatever has yet been contrived to give a Reaſon for it, can at moſt paſs for Conjectures only, ſome of which have been viſibly confuted by Experience: Others ſuppoſe the thing in Queſtion; laſtly others, which are more ingenious than probable, have no Facts to recommend them.

To ſay that a Spring, which is ſtretched by bending it, has it's Pores more open on the convex Side, may indeed be true. That the Pores tho' more open, are not yet open enough to fill themſelves with the groſs Air, and that they continue empty, this may ſtill be probable; but to add, that in Conſequence of theſe little Vacuities, the Preſſure of the Air, which acts on the oppoſite Side, is the Cauſe of the Endeavour, which we ſee the Elaſtick Body to make, to recover it's firſt State; this is what Reaſon does not aſſert, and which Experience expreſsly denies. For Elaſticity performs all it's Functions, as well in a Place deprived of the groſs Air, as elſewhere.

I CALL that ſuppoſing what is in Queſtion, to attribute the Springineſs of Bodies to the Air, which they contain within their Parts as ſo many little Balls, which find themſelves compreſſed in the concave Part of a Staff, which is bent, and which re-act till it is ſtrait again. For it will ſtill remain a Queſtion, what is the Cauſe of the Springinſs of the Air?

LASTLY, If with the Change of Figure, which is made in the Pores of a Spring when bent, we ſuppoſe the Action of a Fluid, which is every where, as the *Materia ſubtilis*, or ſomething like, which acts by it's Weight, we may form an Explication which will have ſome Likeneſs of Truth. But I doubt much whether it will be admitted, if it is not ſupported by Facts; and I cannot ſee how ſuch can be found, that will ſpeak to the Purpoſe.

WHAT we have ſaid in the foregoing Lecture, and in this, concerning the Diviſibility of Bodies, the Subtilty of their Parts, the Variety of their Figures, their Impenetrability and Poroſity; engages us, and puts it within our Power, to explain in general after what Manner we acquire the Knowledge of the Objects that ſurround us. For whatever is without ourſelves, would be unknown to us, if it did not make ſome ſenſible Impreſſion upon us. And this Impreſſion, which aſſumes ſo many different Forms, we owe almoſt entirely to the great Minuteneſs of the Parts, which affect us, and to the different Figures they acquire. Whatever is material applies itſelf to our Senſes, and it is from the Report that they make, that we form our Judgment.

A Digreſſion concerning the SENSES.

CERTAIN Faculties of an animated Body, by which it maintains a Correſpondence with external Objects, we call *Senſes.* Theſe are ſo many Means that the Creator has furniſhed them with, that Animals may be in a Condition of feeding themſelves, of defending themſelves, of aſſiſting one another, and of propagating their Kind. For, without the Senſes, they would hardly differ from a Plant, which grows in the ſame Place where Nature produced it; which withers immediately when it's Nouriſhment fails; and which ſuffers with equal Inſenſibility, either the Spade which cultivates it, or the Knife that deſtroys it.

THE Exerciſe of the Senſes, is meerly an animal Function; it belongs as well to Beaſts as to Men. It ſeems alſo in this Reſpect, that many Species of the Brutes have been better furniſhed than we have been. For what exquiſite Smelling have Dogs! How ſharp of Sight are ſome Birds of Prey!

We commonly diſtinguiſh five different Senſes; the *Touch*, the *Smell*, the *Taſte*, the *Hearing*, and the *Sight*. There are but few Animals, in which we may not reckon up ſo many. Poſſibly there may be Species in Nature, that may have ſome other Senſes that we know nothing of. But it is with this as with all other things, that are not impoſſible; we are not to admit them without Neceſſity, and without Proof. Every Senſe has it's particular Seat in ſome Part of the Body, which in this Reſpect is called it's *Organ*. The Ear is the Organ of Hearing, the Eye of Seeing; and ſo of the reſt.

Tho' every Organ is ſenſible, it is not ſo however for all Sorts of Objects; for every one has it's particular Province. The Ear would direct itſelf in vain towards the Light, and the ſharpeſt Sight could not perceive the Sound of a Bell. Even tho' the Object ſhould belong to the Organ it affects, the natural Senſation would not take Place, unleſs when the Impreſſion is neither too ſtrong nor too weak. We ſhould not diſtinguiſh the Image of the Sun, if we ſhould immediately receive his Rays into our Eyes. And few Perſons could read a Writing in ſmall Characters, if they had only the Light of the Stars.

What is it then *to perceive*, or to make Uſe of our Senſes? On the Part of the Animated Body, 'tis to receive upon ſuch or ſuch an Organ, the moderate Impreſſion of an Object, which affects it either by itſelf, or by ſome intermediate Matter. On the Part of the Soul, which animates the Body, 'tis to recollect,

recollect the Ideas, which it has connected with theſe Impreſſions; or to form new ones, if the Impreſſions are new. If a Man, for Example, in open Day ſhould caſt his Eye upon a Dog: The Light, which illuminates the Body of this Animal, rebounds to the Spectator, and ſtrikes a Place at the Bottom of his Eye, terminated like the Figure of the Animal, which reflects it. On this Occaſion the Soul recollects the Idea of a Dog, which is familiar to it; and if the Memory furniſhes it with the Idea of ſome other Dog, it judges this to be great, little, lean, fat, *&c.* by the Compariſon it makes with it. Now to know how the Organ affected by the Object, determines the Mind to think in conſequence of it; this is what Phyſicks do not pretend to teach us, and is (I believe) what exceeds the Limits of our narrow Comprehenſions. The Union of the Soul and Body; the Intercourſe of theſe two Beings of ſuch different Natures, is one of thoſe Myſteries, which perhaps it is more prudent for us to admire than to pry into.

But as a Man ſees a Dog, ſo does a Dog ſee a Man: And his Actions as well as ours, ſeems to be regulated by what he ſees, by what he underſtands, *&c.* Therefore ſhould it be aſked what paſſes in this Animal, when an Object affects any one of his Senſes? This would be another of thoſe thorny Queſtions, wherein our Curioſity is diſappointed, and upon which the moſt inquiſitive Genius's, have in vain exhauſted all their Philoſophy. According to the Doctrine of *des Cartes*, a Beaſt is nothing elſe but a fine Machine, all the Pieces of which are ſo well matched, and ordered with ſuch perfect Correſpondence, that one of them being moved by the external Object, that has hold of it, immediately determines the reſt to move in ſuch or ſuch a Manner. The Nerves of each Organ being touched as they ought, tranſmit to the Members their different Motions, whence ſuch or ſuch an Action is the reſult. This Thought is grand, and bold; it is even perſuaſive when one conſiders it without Prejudice. But it would weaken it to build it's Probability upon Examples or Similitudes.// An Oyſter or a Snail, which of all animated Beings ſeem to be the moſt infirm, is beyond Compariſon much above the moſt perfect Watch, or whatever elſe Art can produce that is moſt ingenious. The loweſt of Mankind, can never be perſuaded to look upon the Actions of a Horſe, a Hound, *&c.* as the Reſult of a Mechaniſm, which is purely material. To have a Reliſh for this Philoſophy, one muſt be but very little of a Philoſopher.

this
Experience
destroys it

WITHOUT doubt we ſhall rather chooſe to believe, that the Body of a Brute, is animated and governed by an Intelligent Being, which begins to live, and dies with it, and which is the Principle of all it's Thoughts, and of all thoſe Judgments, of which we think we ſee Indications in the ſeveral Actions of Animals. This Opinion is neither contrary to Reaſon, nor to the Doctrines of Religion, and has found Patrons, and ſtill finds them to this Day; and that not only among the Vulgar, who judge only from

Appearances, but even among ſuch as think, and who entertain no Opinions till after they have thoroughly examined them.

BUT it muſt not be thought, that in taking this Side of the Queſtion, we are put above all Difficulties. When we conſider the Docility of a domeſtick Animal; the Craft and Subtilty of certain wild Beaſts of Prey; the Regularity and Induſtry, that prevails among certain Kinds of Inſects, which live and labour in Society; it is very convenient to account for it by ſaying, 'That all theſe Animals are intelligent, 'the Author of Nature has made them ſuch, by 'incloſing in their Bodies a Soul, which is of a Kind 'ſuitable to their Condition'. Now if this Soul is immaterial, as is pretended, what becomes of it? It has been lately obſerved[*], That after a certain Worm has been cut into five or ſix Parts, and often more, every Portion continues to live, and becomes again a compleat Animal, and in all things like to that, which had been divided. Was there then ſeveral Souls in the ſame Individual; or elſe that which is not Matter is it diviſible? We will not urge this Queſtion any farther, in a Work in which all metaphyſical Enquiries are prohibited: But we will apply ourſelves wholly to what may be cleared up, and proved by Experiment and Obſervation. As to the Matter in hand, we ſhall confine ourſelves to explain the Mechaniſm of our Senſations. We will trace the external Object, or it's Action, to the Part of the

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[*] M. *de Reaumur's* Hiſtory of Inſects, Tom. VI. Pr. p. 54.

Body appointed to receive it's Impreſſion; and let us ſee what are the neceſſary Conditions, in the Object to be actively ſenſible, and in the Organ to be effectually affected.

The TOUCH.

The chief, and the moſt general of our Senſes is the *Touch*; we may ſay, that all the reſt are only the *Species*, of which this is the *Genus.* When we hear the Sound of the Voice, or of any Inſtrument, this Senſation is nothing elſe but a tremulous Motion, excited at a certain Part of the Ear, by the Contact of the Air, which itſelf is agitated by the ſonorous Body. When we ſee any Object, 'tis becauſe the Light, which proceeds from that to us, ſtrikes upon the Bottom of the Eye. Thus to *Taſte*, to *See*, to *Hear*, to *Smell Odours*, properly ſpeaking, are to be touched in ſuch or ſuch a Part of the Body, by a certain Matter. Whereas the *Touch*, which we conſider as the firſt Senſe, conſiſts in receiving, upon any whatever ſenſible Part of the Body, the Impreſſion of any Matter whatever. The other Senſes have their Organs, and Objects that are proper to them; this poſſeſſes the whole Habit of the animated Body, and is extended to whatever is palpable. Beſides it has this Advantage over them, to be at the ſame time both Active and Paſſive. For it not only puts it in our Power to judge of what makes an Impreſſion upon us, but likewiſe of what reſiſts our Impulſions. We can apply the Organ to the Object, and it is by

Contact or Handling, that we uſually inform ourſelves of the Condition of thoſe Bodies without us, which it concerns us to know.

THE Bodies that we touch, or which touch us, make different Impreſſions upon us, according to their Magnitude, Figure, their Conſiſtence, the Degree or Kind of their Motion, their Temperature, *&c.* And to all theſe different Manners of Touching, different Names have been given, which expreſs either the Action of the Bodies upon us, or our Action upon them. To *ſtrike*, to *prick*, to *pinch*, to *Scratch*, to *Tickle*, &c. are ſo many Expreſſions, which ſhew what different Bodies make us feel, in conſequence of their Maſs, their Form, or their Manner of moving. *Cold*, *hot*, *hard*, *ſoft*, *dry*, *moiſt*, commonly denote the Senſation, which is excited in us, by a Matter, which we handle, by the actual Condition of the Parts, which compoſe it's Maſs. As the Senſations of Touching may vary *ad infinitum*, either by the Variety of the Object itſelf, by the Extent and Diſpoſition of the Organ, and by the different Manners by which one is applicable to the other; we are very far from being able to characterize all by proper Names. Thoſe, which we have mentioned, and many others, which we omit, are only (as we may ſay) generical Terms, by which we make known, with the aſſiſtance of ſome Circumlocutions, the different Species that may be reduced to them. By *Tickling*, for Example, we denote what we feel in the Throat, when a ſlight Acrimony provokes us to cough. Likewiſe we ſay, that a Medicine *pinches* or *gripes*, to declare that it makes ſtrong Impreſſions upon the Parts which it affects.

THO' the Object of the *Touch* is generally without us, the different Parts of the ſame Body act reciprocally upon one another, both without and within. When the Hand touches the Foot, it creates two Senſations. It is at the ſame time the Object of one, and the Organ of the other. As to what paſſes within, and without Interruption, the Habitude deprives us of the Senſation of it. For Example; the Action of the Fluids upon the Solids does not become ſenſible, but when it brings ſome Change to the natural State: And then we feel what we call *Wearineſs*, *Weakneſs*, or *Pain*.

WE may ſay in general, that in every Organ, the Nerves are the moſt eſſential Part; that in which the Action of the Object is terminated, and after which we can no longer perceive any thing that is mechanical. The Bottom of the Eye, where Viſion is compleated, is only an Expanſion of the optick Nerve. The *Lamina Spiralis* of the *Cochlea*, which is looked upon as having the greateſt ſhare in the Functions of the Ear, is a Compound of nervous Fibres. And the Organ of the Touch is found thro' the whole Extent of the Skin, and eſpecially at it's external Surface; where it is known that all the little Nerves are terminated, which form the greateſt Part of this Tegument. 'Tis thoſe little Nipples, the

Rows of which form Ridges towards the Extremities of the Fingers, where the Touch is generally more exquiſite than elſewhere. A ſkillful Anatomiſt*, has lately given us a very conciſe and intelligible Deſcription of the Skin, in a Work wrote profeſſedly on the Senſes; the reading of which, I think, will be very uſeful to thoſe, who deſire upon this Subject more ample Diſcourſes than what can find a Place here.

WHAT proves beyond Diſpute, that the Nerves have a greater Share in the Touch than any other Part, is becauſe this Senſe exerts it's Functions more or leſs perfectly, according to the actual State of thoſe little nervous Tufts, which we may perceive at the Superficies of the Skin, and which are covered only by the *Epidermis*, Fig. 11. If a Burn dries them up, if any foreign Matter covers them, if too great Cold contracts them, or hinders them from ſpringing out; the Part where this happens loſes it's Senſe, and does not recover it till theſe Accidents are removed. The Diſtempers of the Nerves, which do not go ſo far as to deſtroy their Œconomy, are alſo the more ſevere; becauſe they immediately attack the Organ of Senſations. The *Lethargy* and the *Palſy*, which ſuſpend or ſtop their Functions, generally cauſe Inſenſibility.

ACCIDENTS, Diſeaſes, old Age, often deprive us of our other Senſes. We often ſee blind Men, deaf Men, and People whoſe taſting and ſmelling are almoſt quite worn out: But it is very rare to find a Man, who is univerſally inſenſible. We ſhall ſoon perceive the Reaſon of it when we conſider, how many ways we can feel external Objects as reſiſting, in Compariſon of the organical Parts, which repreſent them to us as ſonorous, coloured, ſavoury, or odoriferous. The Extenſion of the Touch is therefore a Refuge, which Nature has provided for thoſe, who, by any Accident, or vicious Diſpoſition, ſhould find themſelves deprived of their other Faculties. Thus we ſee blind Men, who ſupply the want of Eyes by their Touch; and tho' the Touch be nothing near ſo delicate, as the other Senſes; yet when it is made Uſe of out of meer Neceſſity, and made more perfect by Habit, it performs Wonders. But I would not warrant the Truth of all the Stories that are generally related on this Occaſion; for when any thing approaches near being wonderful, it ſeldom paſſes without great Exaggeration.

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* M. *le Cat's* Treatiſe of the Senſes, p. 207.

The TASTE.

As the Growth and Support of Animals depends on the Nouriſhment they take in, and of the Choice they make of it; it was convenient that Nature ſhould form them in ſuch a Manner, that they themſelves ſhould deſire their neceſſary Aliments, and diſtinguiſh ſuch as were fitteſt for them. It was neceſſary they ſhould feel the need of eating, and that they ſhould take Pleaſure in ſatisfying it. For without this Precaution, the Care of living would have been a Burden. Let us judge of it from ourſelves. Were we only to diſcharge a Duty when we ſit down to eat, it muſt be allowed, that Indigeſtions would not be ſo common, and perhaps we ſhould ſee many People die for want of feeding themſelves. The Author of Nature has foreſeen this Inconvenience, and to prevent it has put Motives within ourſelves, which prevail more powerfully with us than our own Lazineſs can do. A faſting Stomach urges us by Hunger and Thirſt; and the Mouth, which gratifies theſe two Appetites, makes itſelf amends by the Savours which it taſtes, for the Trouble it takes in preparing the Aliments for Digeſtion.

The Taſte conſiſts then in perceiving the Impreſſion of ſavoury Matters, and in receiving or rejecting them, according to the Ideas, which they cauſe to ariſe, and the Judgments, which are formed from them.

Savours, which are the Objects of the Taſte in general, proceed chiefly from the ſaline Parts, which are found in all Matters whether Animal or Vegetable; which we take either as Food or Phyſick. Theſe little angular pungent Bodies are fitter than others to penetrate even to the immediate Organ, and to make themſelves perceived there. We may judge of them, by putting a Grain of pure Salt upon the Tongue, of any Kind whatever, where it will make a very ſtrong Impreſſion. And their Analyſis diſcovers, that of all mixt Bodies, thoſe that affect the Organ moſt, are ſuch as abound moſt in Salts.

We know but a very ſmall Number of Salts that are eſſentially different, or of which the Parts divided by Water ſhew themſelves under Figures, which are conſtantly different. Thence it follows, that the Senſations of the Taſte would be but little diverſified, if the ſaline Parts contained by the Aliments were to act alone, and without Mixture upon the Organ. But Nature has mingled them with other Principles, which are not ſavoury of themſelves, which only act as Objects of the Touch in general, and of which the Number and Quantities, may be combined *ad infinitum.* Water, Earth, Air, Sulphur, Oil, are ſo many inſipid Matters, which Nature has formed as an Ingredient into almoſt every thing, that ſerves for the Nouriſhment of Animals. The Mouth in bruiſing theſe Aliments ſupplies a Lymph, which promotes the Diſunion of the Parts, and which lays open their Principles. But this Diſſolvent has not ſo much hold upon ſome as upon others. The Sulphur and the Oil, for Example, do not ſubmit to it's Action, which the Earth and the Water do. So that the ſaline Part never diſengages itſelf but imperfectly, and in Proportion to the Diſſolubility of that which is cloſely united to it.

THE moſt ſimple Savours, and upon which Men are more generally agreed, are thoſe wherein the Salts are the leaſt mitigated by the Mixture of other Matters. Every Body knows what it is to be *ſalt*, *ſour*, *ſweet*, *bitter*, *harſh*, &c. Theſe different Senſations are ſo remarkable, that they are preſently diſtinguiſhed. They are as it were the Baſis of all others, which become ſo much the more difficult to deſcribe and expreſs, the more they recede from this primary Simplicity. The Bitterneſs of Coffee, for Example, corrected by the Sweetneſs of Sugar, produces a mixt Senſation. The Juice of Fruits mingled with Spirit of Wine, takes a new Taſte. The Taſte of Victuals changes almoſt entirely, and is diſguiſed a thouſand different ways, by that infinite Number of Preparations and Mixtures, which Daintineſs has made an important Art, and which has been much cultivated in our Age.

IT is with the Object of the Taſte, as with that of the Touch. Mixt Savours depend on certain Principles, the Aſſemblage of which is capable of infinite Combinations, ſo that it is impoſſible to mark them all by particular Names. They are expreſſed by comparing them to ſome Savour that is more ſimple, or better known. Thus we ſay, *Such a Fruit is a little tart*, or *bitter*. *Such a Fiſh has the Taſte of a Pike*, &c.

As to the Organ of Taſte, all Anatomiſts have agreed, that it is chiefly in the Tongue. A great many of them think, that it is through the whole inſide of the Mouth, and many extend it as far as the Gullet, or even to the Stomach. It is hardly poſſible to reſtrain it to the Tongue alone. Every one may know from his own Experience, that ſavoury Matters make themſelves perceived, tho' more faintly, at the Palate and the Bottom of the Mouth. But what determines the Queſton is this, that People have been known who had no Tongue, and yet taſted their Food.*

Here alſo the Extremities of the nervous Fibres, thoſe Nipples we mentioned before, are the immediate Organ of Taſte. But whereas for the Senſation of touching they are ſmall, and covered over by a pretty ſmooth Skin of ſomething of a cloſe Texture; in all the Parts of the Mouth where they are obſerved, and eſpecially in the Tongue, *Fig.* 12. they are bigger, leſs compact, and as it were ſet into a Covering or Sheath very porous, and watered by a Lymph which keeps them ſupple, and puts the ſavoury Parts of the Aliments in a Condition to touch them, which is neceſſary to make it perceived. For it divides it, it unfolds it in ſuch a manner, that it gives it the degree of Tenuity, proper to inſinuate itſelf through this very porous Skin, that covers the little nervous Tufts, upon which the Impreſſion is to be made.

*And some
no Palate
have Taste
while
others
with a
Palate &
have had
no Taste
even of
Stinking
Meat &
that to my
Knowledge

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* Memoirs of the Academy, for 1718. p. 6.

The Organ of Taſte may be ſpoiled and worn out as well as others, by a too immoderate Uſe of it's Object. The ſtrong Savours, ſuch as ſpirituous Liquors, and thoſe high-ſeaſoned Ragoûts ſo much in Faſhion at this Day, much diminiſh the Senſibility of thoſe Parts, which are often to undergo the Impreſſion of them. Experience teaches us, that the ordinary People, who accuſtom themſelves to drink Gin or Brandy, find Wine too inſipid for them, and therefore do not regard it. We know on the contrary, that Drinkers of Water have generally their Taſte more nice and exquiſite than others. This Liquor, which has hardly any Savour, preſerves the Organ in it's full Senſibility, becauſe it is not capable of altering the Texture of it. Diſeaſes or old Age may alſo create a Diſorder in this Part. At the beginning of a Recovery from Sickneſs it often happens, that we have no Taſte for our Food; becauſe there ſtill remains ſome vicious Humour, that choaks up the Pores, through which the ſavoury Particles ought to paſs; or becauſe ſome preceding Accidents have cauſed an Alteration in the Organ itſelf, which is not yet returned to it's natural State. But I have inſenſibly paſſed the Boundaries of my Undertaking; and it belongs to Phyſick and Anatomy, to ſupply what may be farther added; though poſſibly I have already ſaid but too much.

The SMELLING.

THE Smelling, to which we aſſign the third Place among the Senſes, when we begin with thoſe, which, in Appearance, are the moſt groſs; yet may be reckoned in the ſecond Place, if we have Regard to the Order that Nature obſerves in their Exerciſe. For it's Functions often precede thoſe of the Taſte. What is offered us to eat or drink is hardly admitted, till it is firſt examined and approved by this Senſe. And Animals which have their Touch neither ſo familiar nor ſo nice as we have, by the Uſe of their Noſe determine about the Quality of their Food, eſpecially when it is new to them, and when they cannot diſcern any outward Reſemblance to what they have been accuſtomed to. There is ſo great an Affinity between the Taſte and the Smell, as well in reſpect of the Object as the Organ, that ſome Anatomiſts have conſidered the latter as a Part or Supplement to the former. And indeed we ſee, that whatever is friendly to one, naturally pleaſes the other. One is tempted to put to one's Mouth, ſuch Matters as exhale agreeable Odours, unleſs we know otherwiſe that it has hurtful Qualities. And if it happens, that any cuſtomary Food diſpleaſes our Smell; either Habit, or ſome powerful Motive muſt prevail over that Repugnance that will not fail to ariſe, without which we ſhould deny ourſelves the Uſe of it, upon the ſole Teſtimony of our Noſe.

As the Inſide of the Noſe communicates with the Mouth, it often happens, that the Senſations of the Taſte are connected, and as we may ſay confounded, with thoſe of the Smelling. This Effect happens, when the Savours are ſpirituous and volatile. And thence again proceeds a prodigious Variety of Senſations, according as the Smell has a greater or a leſſer Share therein. When it partakes a little too much of it, as it's Organ is more ſenſible than that of the Taſte, this loſes it's Right for a Moment, and the whole Senſation belongs to the Smelling. Who is a Stranger to what happens, when we take a Doſe of Muſtard a little too large; or when we drink too deep of ſtrong Beer?

It appears that the principal Object of the Smelling are Volatile Salts, and that the Variety of Odours proceeds from the Mixture and the Quantity of other Principles, that are conjoined with them. For the fixt Salts are not able to apply themſelves to the Organ; and whatever is not ſalt in mixt Bodies, tho' it may be volatile, ſeems inſipid to the Smell as well as to the Taſte. We obſerve, on the contrary, that whatever promotes the Evaporation of the Matters wherein volatile Salt abounds, whatever opens their Principles, alſo makes them more odoriferous. When Meat is dreſſing, the Action of the Fire divides the Parts, ſubtilizes them, and puts them in a

State

State of Exhalation, and then the Scent becomes very ſenſible. When we mingle Sal Ammoniac in Powder with Quick-Lime, or with Salt of Tartar, the urinous volatile unfolds, raiſes itſelf, and ſmells very ſtrong.

For the ſame Reaſon Fermentation, or Putrefaction, always make thoſe Matters ſmell very ſtrong, which in their natural State ſmell very little, or nothing, and they generally change the Quality of the Odours. For theſe inteſtine Motions, give occaſion to the Parts to diſplace one another, and to diſunite. If this Diſunion does not go ſo far as to decompound the little Cluſters, and to change the Nature of the Mixture as it begins to ferment; it becomes only more odorous, becauſe it exhales in a greater Quantity. But if the Principles themſelves, which compoſe the integral Parts, come to ſeparate, not only the Odour becomes ſtronger and more penetrating, becauſe the Organ will be affected by more ſubtile Parts; but the Senſation alſo will be of another Species, becauſe it will be excited by Corpuſcles of a different Structure, wherein the ſaline Part, which is the principal Agent, will be more or leſs abundant, or more or leſs opened. Fruit as it grows rotten, Fleſh when it corrupts, exhale Odours more and more diſagreeable, not only becauſe they are ſtronger, but alſo becauſe they become more fetid, the farther the Corruption proceeds.

Odours are ſtill leſs to be deſcribed and characterized than Savours themſelves. We are hardly agreed on any fundamental Senſations of this Kind.

We content ourſelves with reducing thoſe that are leſs known, to thoſe that are more ſo; as to the Fume of Sulphur, to that of burning Linnen, to the Vapour of Urine, to the ſmell of a Violet, of Citron, of Amber, *&c.* without any Pretenſion however, that theſe different Exhalations are ſimple Odours.

It muſt needs be, that the Corpuſcles, capable of moving the Organ of Smelling, are ſuſceptible of a prodigious Diviſibility. We may judge of it by the Experiment, and by ſome Obſervations, which we have produced in the firſt Lecture *, to prove in general, to what an immenſe degree Bodies are diviſible. Theſe little exhaled Parts float in the Air, and 'tis this Fluid that carries them to the inward Parts of the Noſe, where the Organ is ſituate; when by Reſpiration we determine it to paſs this way.

The internal Part of the Noſe is covered with a Membrane, which Men of Art call *Pituitary.* 'Tis a Texture compoſed for the moſt Part of the Fibres of the olfactory Nerve, which is generally acknowledged to be the Subject of Odours. Theſe nervous Fibres, terminate at the Superficies of the Membrane, in the form of little Nipples, upon which the Impreſſion of the odoriferous Corpuſcles is made. See *Fig.* 13. This in ſhort, is the Organ of Smelling; a longer Deſcription would be improper here. Thoſe who would be inſtructed more at large, will find it much to their Satisfaction in the Treatiſe of

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* and *third* Experiment.

M. *le Cat*, which we have quoted above; alſo in M. *Winſlow*'s Anatomical Explanations, and elſewhere. We ſhall only add, that ſtrong Odours, and a too frequent Uſe of them, harden (as we may ſay) the little nervous Tufts to which they are applied, and make them loſe that delicate Senſe, which thoſe Perſons enjoy, who abſtain from the Uſe of Snuff and Perfumes. We may alſo loſe for a Time the Uſe of this Senſe, when there is a ſuperabundant Humour, or when it is too thick, which inſtead of moiſtening the Organ as much as is neceſſary, to keep it ſupple and ſenſible, choaks and ſwells up it's whole Subſtance. For then it not only ceaſes to be in it's natural State, and well diſpoſed to diſcharge it's Functions; but the Air, which paſſes with Difficulty, does not carry with it the ſame Quantity of Odour. This is what we find, and is eaſily obſerved, in that Indiſpoſition which is called a Defluxion from the Brain.

We ſhall ſay nothing here about the Hearing and the Sight, becauſe we ſhall have Occaſion to explain the Mechaniſm of theſe two Senſes, when we come to treat of Sounds and of Light. It remains only to finiſh this Digreſſion, by ſome Remarks which may ſtill be made, upon the Senſes in general conſidered in Man.

1. Tho' according to the Intention of Nature, every Individual of our Species ought to make ſuch Uſe of his Senſes as they were given him for; yet it is not to be doubted, but that all theſe Faculties

are not in the ſame Degree of Delicacy in all Men.

THERE have been ſome* whoſe Smelling was as exquiſite as that of Hounds. Others could diſtinguiſh Objects in Places ſo obſcure, as that People of ordinary Sight could not perceive them. Some Epicures find in Ragoûts and Liquors ſuch different Flavours, as eſcape the Obſervation of common Palates. Such a Degree of Perfection in the Senſes, when it is not at the Expence of ſome other Advantage more valuable, ought to be looked on as one of Nature's Bleſſings. But that the Senſibility of our Organs ſhould be within Bounds, and that our Senſations ſhould not have the utmoſt Extent they might have had, is not a Misfortune to us, and we have no Reaſon to complain of it. On the contrary, a much greater Delicacy of the Senſes than is commonly found, would expoſe us to many Inconveniencies, unleſs at the ſame Time a Reformation was made in the Objects which have been uſed to affect them, and that we ſhould alſo change our Manner of thinking. Too much Light hurts our Eyes, ſuch as they are now. If they were more nice, an ordinary Brightneſs would be always too much for them, and we ſhould never ſee without Pain. Would it be agreeable always to ſee Objects in the Manner we ſee them through a Microſcope? The fineſt Skin would then appear nothing elſe but a rough Tegument, every where full of Blotches and Wrinkles. And the brighteſt Diamond would ſhew us only ill-prepared Faces, and without Beauty or Symmetry. And this Reflexion may eaſily be applied to the reſt of the Senſes.

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* Journal *des Sçavans*, Apr. 1667. Memoires *de Trevoux*, Feb. 1725.

2. IT often happens in the Uſe of the Senſes, that though the Organ may be ſufficiently affected by the Object, yet the Senſation has not it's Effect in reſpect of the Mind. How often does it happen, that one may have his Eyes open upon an enlightened Object, and yet not ſee it? Or that one may ſpeak loud enough to a Perſon that is not deaf, and yet he may not hear us? All the Bodies that touch us, or which we touch by Chance, do they therefore come to our Cognizance? 'Tis becauſe in order to know what touches us, we muſt feel it. In order to hear, we muſt hearken. In order to ſee, we muſt behold. But to feel, to hearken, to behold, is not only to ſuffer the Object to act upon the Organ; it is to join the Attention of the Mind, to the Exerciſe of the Senſe which is in Function. An abſent or unattentive Man often behaves like a deaf, blind, or inſenſible Man. Who is it that does not know the Effects of Abſence of Mind?

3. THE Senſations, as we have obſerved before, excite our Ideas, and theſe Ideas are agreeable or diſpleaſing to the Soul that conceives them. But what is more remarkable is this, that the ſame Object is the Cauſe of pleaſure to ſome, and is diſagree-

able to others. Some Perſons love Bitters, but the greateſt Number abhor them. Certain Odours pleaſe theſe, and are inſupportable to thoſe. This is what has given Occaſion to the common Maxim, That there can be no Diſpute about Taſtes. But ſtill farther: That Senſation which gave me Uneaſineſs ſome Years ago, is now become pleaſing to me. Such a Man ſhewed Diſguſt in drinking Beer, or in taking Tobacco for the firſt time; afterwards it became his Delight. The Scent of Muſk, which was all the Faſhion formerly, now gives a Man the Head-ach. Are not the Organs nearly the ſame in all Men? And in the ſame Individual, are they liable to change from Time to Time?

As it is a thing well known, that the organical Parts are more delicate in ſome Perſons than in others, and conſequently more ſuſceptible of Impreſſions; and that the immoderate Action of the Object may be hurtful to them; it may thence happen, that what is only an ordinary Senſation for ſome, may be for others a violent Irritation, troubleſome and diſquieting to the Soul, which watches for the Preſervation of the Body, and which is diſguſted at every thing that has a Tendency to diſorder the animal Œeconomy.

But it muſt be owned, that the Imagination has as great a Share as any other Cauſe in all theſe Varieties. Objects pleaſe us, or give us Diſguſt, according to the Ideas we have connected with them. And theſe Ideas depend much on Habit, on the Faſhion, and on Prejudices. We have heard it ſaid by People whom we thought Men of Taſte, that ſuch a Matter, while burning, produced a good Odour. This is enough to make us like it when we try it. When we firſt ſaw Oyſters, our Eyes would poſſibly give us but a diſagreeable Repreſentation of them; but by little and little theſe firſt Ideas grow weak, and yield to others more pleaſing, which we conceived upon taſting them. Thus as our Senſations partly depend on the Diſpoſition of the Organ, the Judgments which follow them are much influenced by the Diſpoſitions of the Soul.

LECTURES IN Experimental Philoſophy.

LECTURE III.

Of the Mobility of Bodies; of Motion, of it's Laws and Properties.

SECTION I.

Of the Mobility of BODIES.

WE muſt not confound *Mobility* with *Motion*; theſe are two Things entirely different. The firſt is a Property common to all Bodies; the other is a State out of which they are often conſidered, and which is not eſſential to them. I ſometimes repreſent to myſelf ſuch or ſuch a Matter as being at Reſt, but I always conceive it may receive the Motion it has not at preſent.

MOBILITY is founded upon certain Diſpoſitions, which are not found in the ſame degree in all Bodies. What makes ſome have more Mobility than others is this, that we need apply leſs Force to make them paſs from Reſt to Motion. The chief of theſe Diſpoſitions are Figure, Smoothneſs of Surface, and the Quantity of Matter contained under the Volume of the Body we intend to move.

TO conceive this with eaſe, let us repreſent to ourſelves firſt two Maſſes of *Glaſs*, *Ivory*, &c. of equal Weight, one of which is a Cube, the other a Bowl, both ſet upon a Table. Theſe two Bodies will only differ in Figure; but this will be ſufficient to make the laſt much more apt than the firſt to receive and preſerve Motion. Let us now give them the ſame Figure, without changing any thing in the Equality of their Maſſes. But let us only conceive, that the Surface of one is uneven, and that of the other ſmooth. This Difference will make this Body more mobile. For leſs Force will make it move upon a ſolid Plain, or in a Fluid. Finally let us ſuppoſe the two Bodies alike as to Figure, and in the Poliſh of their Surfaces, but differing as to their Quantity of Matter; one for Inſtance a Ball of Ivory, the other of Lead, both of the ſame Diameter, ſuſpended alike, or ſet upon the ſame ſtrait horizontal Plain. Muſt not this latter be ſtruck with more Force in order to move it, than the other? Or the ſame Force being impreſſed on each of them, will it not find leſs Reſiſtance in the lighter than in the heavier?

THIS Reluctance to Motion, which we perceive in all Bodies, having Reſpect only to their Maſs, is called the Force of Inactivity. It is, as well as Gravity, proportional to the Quantity of Matter belonging to every Body. But though theſe two Forces have this in common with each other, yet we cannot ſay they are the ſame Thing; for there are Proofs to the contrary. Gravity, as we ſhall ſee afterwards, always exerts it's Action from above downwards, and as far as it may perpendicularly to the Horizon. But the Force of Inactivity or of Sluggiſhneſs, reſiſts Motion which ever way we attempt to move a Body.

To attain to a juſt Idea of this Sluggiſhneſs, let us repreſent the Experiment propoſed by Sir *Iſaac Newton*. *Fig.* 1. Let us conceive a Body of a determinate Magnitude and Weight, for Example, a Ball of Lead of a Pound Weight, ſuſpended freely by a long Thread in a quiet Air, and another like Ball of Lead ſuſpended in the ſame Manner, which ſtrikes againſt the firſt with four Degrees of Velocity. If the Ball at Reſt gave no Reſiſtance to that which ſtrikes it, after the Stroke we ſhould ſee them both move with four Degrees of Velocity. For why ſhould the Motion diminiſh in the Ball that ſtrikes, if it met with no Reſiſtance from the Ball that is ſtruck? And why ſhould not the Ball that is removed, be removed by the whole Motion of the Ball that drives it on? But Experience teaches us quite another Thing. The Ball at Reſt receives from that which ſtrikes it only a Part of it's Motion; and this laſt loſes by the Stroke what the other appears to have acquired. Therefore a Body at Reſt makes a real Reſiſtance to that Effort, which endeavours to move it. But farther ſtill. If the Ball at Reſt, *Fig.* 2. weighs 30 or 40 Pounds, the other Ball, which has then a much leſs Maſs, with the ſame Effort does not carry it ſo far as in the foregoing Caſe. Yet if to move any Body whatever, nothing elſe was required but to make it loſe it's State of Reſt; the Motion communicated would be the ſame whether in a greater or in a leſſer Maſs. Therefore there is ſomething more to be overcome, than a meer Privation of Motion.

CAN it be ſaid, that the Ball at Reſt reſiſts for no other Reaſon, but becauſe it is ſupported by the Air that ſurrounds it, and which muſt be firſt removed before it can change it's Place? But firſt, Bodies that are ſtruck in a Vacuum ſhew the ſame thing as in the Air; or if there is any Difference, it is not ſenſible.

SECONDLY, the Reſiſtance of the Air itſelf makes a Part of the preſent Queſtion; for we are treating of the Sluggiſhneſs of Bodies in general. If the Air, as Matter, gives a Reſiſtance to the Motion of the Bodies which endeavour to diſplace it, and this is agreed on, it's Sluggiſhneſs is proved.

THIRDLY, if the Reſiſtance made by the Ball at Reſt proceeded only from that of the Air, by which it is ſupported; to reſiſt as much again it muſt anſwer to a Volume of Air as big again. But the Fact is, that it is enough to double the Weight of the Ball;

and it is well known, that a ſpherical Solid, in order to have a double Maſs, muſt not acquire a Surface as big again as it had before.

CAN it be then the Gravity of the ſuſpended Ball that can oppoſe itſelf to it's Removal? Of whatever Length the Thread is ſuppoſed, it may be ſaid, if the heavy Body which it keeps ſuſpended is free, it will keep it ſtretched in a vertical Situation, and will place itſelf in the loweſt Point which the Suſpenſion will ſuffer it to obtain. Whence it follows, that if we force it from thence, to whatever Place it is carried round about, it will ſtill be higher; and to carry it thither it's Gravity muſt be overcome, which endeavours to keep it where it is.

THIS Objection is ſpecious, but not ſufficient to prove, that the Force of Sluggiſhneſs and of Gravity are the ſame thing in Bodies; if we do but conſider, that in the ſuſpended Balls of the Experiments referred to, the Reſiſtance is always proportional to the Maſſes eſtimated according to their full Value. Whereas the Gravity, at the Time of Reſt, is reduced to nothing by the Thread which ſuſpends the Ball; and that it hardly acts at all when the Ball is put in Motion, if the Thread be very long, as we ſuppoſe it to be; and that we only make it deſcribe ſmall Arches.

TO make this more intelligible, let us ſuppoſe the Ball at Reſt at the End of the String which keeps it ſuſpended. Then the whole Effort of Gravity is overcome by the Reſiſtance of the Point of Suſpenſion. If we puſh it with the Finger into an Arch of a Circle, in Proportion as it withdraws from the

Place of Reſt, we may perceive that it gravitates more and more upon the Hand that directs it; ſo that if the Thread becomes Horizontal, it makes it's whole Weight to be perceived. And when we guide it in deſcending through the ſame Arch of a Circle, we feel the Effort of Gravity to decreaſe proportionally, till the String becomes vertical, and that the Point of Suſpenſion is then loaded with the whole. We may conclude then that the Ball in queſtion does not reſiſt as it is heavy, but when the Thread is no longer vertical, or when it has paſſed from the loweſt Place, to another that is higher. This Removal then muſt neceſſarily precede the Reſiſtance, or the Endeavour, which proceeds from Gravity. But to effect this Removal, a real Force muſt be employed, capable of overcoming and removing the whole Maſs of the Ball. For, if the Force ſo employed is too little, it is nevertheleſs a real Force; and yet it has not the required Effect upon a ſolid Body, the Parts of which are united together. Thus the ſuſpended Ball has given a Reſiſtance, which it was neceſſary to overcome, before it's Gravity could be perceived.

Also *Fluids* reſiſt as well as other Bodies. When a Solid is moved in Water, according to an horizontal Direction, it cannot be ſaid that the Reſiſtance it finds, proceeds from the Gravity of the Medium; ſince all the Parts of this Medium, which we ſuppoſe to be homogeneous, are in *Equilibrium* with one another, and that we have nothing to expect from their Weight; ſince we can remove them according to a Direction, which is indifferent to them; ſuch as we have ſuppoſed.

FINALLY the Force of Inactivity is diſcoverable in Bodies in Motion; as well as in thoſe, which are at Reſt. That which moves with only two Degrees of Velocity will not receive a third, till a new Effort be made, in order to give it this new Degree. The ſame Reſiſtance, which oppoſed the firſt Force, that took away it's Reſt, it alike employs againſt that, which would make an Addition to it's new State. Wherefore after having produced the Experiments which prove the Force of Inactivity in Bodies at Reſt; I ſhall add one, which to me appears deciſive, and which will not ſuffer us to confound the Effects of Sluggiſhneſs or Inactivity, with thoſe of Gravity.

EXPERIMENT I.

PREPARATION.

THE Machine, which is repreſented by *Fig.* 3, at the Diſtance of ſix Feet high, carries two Ivory Balls A and B, each of an Inch and half Diameter, and joined together by a little Piece of Wax. The Hammer D, which is of the ſame Matter as the Balls, is guided by a Spring, which is more or leſs bent; and which unbends when the String E is drawn, and makes the Hammer ſtrike upon either of the two Balls.

EFFECTS.

B, ONE of the two Ivory Balls, being ſtruck by the Hammer, parts from A which is the other, and goes before it in falling.

EXPLANATIONS.

IF the two Balls, when ſeparated from one another, complied only with their Gravity, as we ſuppoſe that they begin to fall at the ſame time, that they are alike in every thing, and move in the ſame Air; it is certain that they muſt arrive together at the Plain, which terminates their Fall. But one of them having received a Blow with the Hammer, which adds to the Effort of it's Gravity, obeys likewiſe this new Impulſe, the Effect of which is to make it outgo the other. And this Preceſſion is ſtill the greater, the ſmarter the Stroke is, which it receives from the Hammer. This is now a new Effect, which cannot be imputed to Gravity, ſince to produce it, a particular Cauſe was applied, without which it would not have been, and of which it follows the Proportion exactly. Now whatever deſtroys an active Force is called Reſiſtance. Therefore a Body, which falls freely, reſiſts a Motion, which is more quick than that of it's Weight, and does not receive it but by another Power, the Action of which is ſuſceptible of all Degrees of more or leſs.

APPLICATIONS.

IF we throw a Stone with our Hand againſt a Tree of a moderate ſize, it will there cauſe an Emotion, which paſſes directly to the Branches; and the Stone falls at the Foot of the Tree, without any farther Motion. Such a Stone thrown againſt a Rock ſtanding by itſelf, falls back in like manner, but we can perceive no Motion communicated to the Rock. We ſee immediately the Cauſe of this Difference, if we conſider, that whatever is material oppoſes it's Inactivity to the Shock of other Bodies; and that this Force, by which it reſiſts Motion, is always proportional to it's Maſs. If we ſuppoſe the Stone moved ſucceſſively with the ſame Violence both againſt the Tree and the Rock, the firſt having much leſs Matter, made too weak a Reſiſtance entirely to deſtroy the Force, which urged it to move, and therefore was ſomething diſplaced; which diſplacing was made ſenſible by the ſhaking of the Branches. The other having a much greater Maſs, made a more compleat Reſiſtance, and was therefore, as we may ſay, victorious. And the Effort of the Stone being diſtributed but to a certain Number of it's Parts, was not ſufficient to be extended to them all in a ſenſible Manner, or ſo as to move the whole Body.

WE have ſeen above, that a Ball of Lead weighing one Pound, which hits againſt another Ball of the ſame Matter and Weight, gives it a certain Quantity of Motion; and that it gives leſs Motion, or to ſpeak more properly, it leſs diſplaces a third Ball that weighs 30 or 40 times as much. We concluded from thence, as we ought, that this latter Body, having more Matter, reſiſted more. From whence it follows, that the greater the Maſs is, the greater Reſiſtance it will make; and, laſtly, that it may have ſo much, as that the Effort it has to ſuſtain, may not ſuffice to be ſenſibly diſtributed into all it's Parts. But the Body cannot be removed, unleſs all it's Parts remove together. 'Tis therefore for this Reaſon, that the Inactivity of Bodies preſerves ſome ſenſibly at Reſt, againſt the ſame Attempt, which would put others in Motion.

* * *

SECTION

SECTION II.

Of MOTION *in general, and it's* PROPERTIES.

WE call *Motion* that State of a Body, when it is actually transferred from one Place to another, whether we conſider it in the whole, or whether we have Regard to it's Parts only. Thus the Boat, which we deliver up to the Current of the River, is in Motion; becauſe it changes it's Place continually. And we cannot deny that the Wings of a Wind-Mill move, tho' they turn about in the ſame Place; becauſe each of them paſſes ſucceſſively through all the Points of the Circle, which it deſcribes.

As often as a Body is moved, it changes it's Situation in reſpect of the Bodies that ſurround it, either near or far off. A Man, for Inſtance, that ſits in a Coach, or is carried in a Boat, changes continually his Relation, if not to the Perſons that accompany him, yet at leaſt in reſpect of the ſeveral Places he paſſes through in his Journey.

If I perceive that on my left Hand, which was before on my right Hand, I may then conclude with certainty, that there has been a real Motion; but this Change of Relation is not itſelf enough to inform me, whether it be myſelf who have paſſed from the Place I poſſeſſed to another. For the ſame Effect would happen if I had been conſtantly at Reſt, if what I had round about me had changed it's Place. Whether the Sun goes about the Earth in 24 Hours, or whether the Earth turns about itſelf in the ſame time, and preſents ſucceſſively all the Points of it's Surface towards this Luminary, it will be the ſame Thing as to Appearances. And that Syſtem which imputes real Motion to our Globe, in order to explain the different Aſpects of the Heavens, would never have been any thing elſe but a meer Hypotheſis, and would have had no Advantage over the contrary Opinion, had it not been otherwiſe ſupported by ſtronger Reaſons, than the relative Poſitions of the heavenly Bodies to the Earth.

There are three Things to be chiefly conſidered in a moving Body; it's *Direction*, it's *Velocity*, and the *Quantity* of it's *Motion*.

The Direction is expreſſed by the right Line that a Body deſcribes, or attempts to deſcribe by it's Motion. For tho' it runs through a Space, which beſides it's Length has the other Dimenſions which it has itſelf; yet, as if it's Matter were reduced to a Point, in it's Direction nothing elſe is conſidered but the Path deſcribed by this Point alone. Therefore by naming only two Terms, we ſhew without any Equivocation, in what Manner a moving thing is directed. As when we ſay, ſuch a River runs from Eaſt to Weſt. Such an Object paſſes from right to left.

WHEN a Body begins to move, 'tis always in a right Line, which it continues to purſue as long as it can. And when it is obliged to leave it, it begins to deſcribe another of the ſame Kind, which it does not forſake, but when it is forced to direct itſelf otherwiſe; but always in a right Line, as we ſhall ſhew afterwards. So that when a Motion is performed in a curve Line, this Curve is nothing elſe but a Succeſſion of little right Lines differently directed. The Sling which we make to whirle round in a Circle, paſſes through an infinite Number of Directions, and the Circle it deſcribes may be conſidered as a Polygon of an infinite Number of Sides.

As many different Names are given to the Directions of Bodies in Motion, as belong to the relative Poſitions of right Lines. We ſay, for Example, that ſuch a Body moves *obliquely*, *parallelly*, *perpendicularly*, &c. to the Horizon, or to ſuch or ſuch a Plain. The Direction of Rain is oblique to the Horizon when the Wind blows.

THE Velocity of Motion, is known by the Space which the Body paſſes through, and the Time it takes up in paſſing. To have a diſtinct Idea of his Velocity, it is not enough to ſay, that a Man has travelled ten Leagues; we muſt know likewiſe in how many Hours he did it.

Besides, when the Queſtion is about relative Velocities, it is not enough to compare the Times, or the Spaces only, to know in what Ratio the Velocities of two Bodies are; we muſt divide the Spaces by the Times. And if we find, for Example, that in equal Times each of them has deſcribed a Fathom, we may conclude there was an Equality of Velocity. And on the contrary there was an Inequality of Velocity, if one of them takes up more Time in deſcribing a given Space; or if in a given Time it does not deſcribe ſo long a Space as the other. The Hands of a Clock or a Watch move round the Dial-Plate. They paſs over the ſame Space, but the Hour-Hand takes up 12 times as much Time as that of the Minutes. The latter then has 12 times as much Velocity as the former. Or elſe in taking the the Time of 12 Hours for a common Meaſure, we ſhall ſee by comparing the Spaces deſcribed together, that the Minute-Hand paſſes 12 times through that Space, which the Hour-Hand paſſes through but once, which comes to the ſame thing as before.

The Velocity of a Body is often confounded with it's Motion. If we make a Piece of Cork to turn about as faſt again as a Piece of Lead of the ſame Volume, it is commonly ſaid, that the Cork has moſt Motion. But this Expreſſion is not accurate, and we ſhall ſee quickly, that more or leſs Motion does not proceed wholly from the Degree of Velocity. Yet even thoſe who are not ignorant of this, ſometimes conform themſelves to common Cuſtom; and we ſay, an *uniform*, *accelerated*, or *retarded* Motion; tho' theſe Modifications ought always to be underſtood of the Velocity of the Motion.

UNIFORM Velocity is that, when a Body deſcribes equal Spaces in equal Times. As if a Bowl running upon a Plain, ſhould deſcribe one Furlong in a Second of Time, another Furlong in the next Second, a third Furlong in the third Second, and ſo on. So that the Times and the Spaces deſcribed may always be equal to one another. We eaſily conceive this Uniformity to be poſſible; but in the natural State of Things it is hardly ever to be found, by reaſon of the inevitable Obſtacles, of which we ſhall diſcourſe hereafter.

WE call accelerated Velocity that of a Body, which in equal Times meaſures out Spaces that go on continually increaſing. Or elſe Spaces that are equal to one another, but are deſcribed in Times that decreaſe more and more. As a Stone which falling freely, will go faſter and faſter towards the End of the Fall than at the Beginning.

IF on the contrary equal Spaces are not performed but in Times that increaſe more and more; or ſuppoſing an Equality of Times, if the Spaces deſcribed go on always decreaſing; this Velocity will be called retarded. Such is that of a Ball rolling on the Ground, which goes ſlower and ſlower till at laſt it comes to Reſt.

THE Quantity of Motion is eſtimated by the Maſs and the Velocity taken together; ſo that by multiplying one by the other, we may exactly know the

Ratio of the Motions of the two Bodies we would compare. Suppoſe, for Example, that one of the two has 100 Grains of Matter, and the other 500; and that both of them move with 4 Degrees of Velocity. The Quantity of Motion in the firſt will be 100 × 4, or 400. And in the other it will be 500 × 4, or 2000. Thus theſe two Quantities of Motion compared, will be as 400 and 2000. We may eaſily perceive the Reaſon why we muſt thus eſtimate the Quantity of Motion, when we conſider, that all the Velocity with which we make a Body to move equally, belongs to all the Parts of it's Maſs. For if I put a whole Body in a Condition of deſcribing a Furlong in a Second of Time, I ſhall determine it's Velocity by that, but I impreſs this Velocity on all the Parts which compoſe this whole Body. So that if after the Impulſe received they ſhould happen to diſunite, we cannot conceive that any of them will be at Reſt. On the contrary we perceive, that all of them equally obeying the ſame Cauſe which has determined them to move, they will continue to perform ſeparately what they had begun in common; abſtracting however from the Obſtacles, which increaſe in Conſequence of this Diſunion, and which we ſhall explain elſewhere.

A Body in Motion may move others, and this Faculty is likewiſe relative to it's Maſs and to it's Velocity, ſo that one of them may be recompenced by the other. For that whoſe Maſs is but ſmall may make as great an Effort with much Velocity, as the other can make with leſs Velocity, if it has a greater

Maſs. With a ſmall Hammer which ſtrikes ſmartly, one may drive the ſame Nail as far as one can with a larger Hammer that ſtrikes but ſlowly. A ſmall Stick does not hurt ſo much as a large Cane, tho' both ſtrike with the ſame Velocity.

THE Motion of Body, when it is made Uſe of to move others, whether it has only a Tendency to move them, or whether it does actually move them, is called a *Power*, or a *moving Force*.

IT has always been thought that this Force, in all Caſes indifferently ought to be eſtimated, like the Quantity of Motion, by the Maſs and Velocity conjunctly. And indeed, if a Body is urged to move, whether it does really move, or whether it is withheld from Motion by Obſtacles, we can find nothing elſe in it but it's Velocity, multiplied as often as it has ſolid Parts; or (which is the ſame Thing) the whole Maſs multiplyed by it's ſimple Velocity. And we cannot perceive, either that invincible Oppoſitions, or a Liberty of Action, can make any Change in the Quantity of Matter, or in the Impulſe that has once regulated the Degree of it's Velocity.

YET ſeveral famous Philoſophers have embraced the Sentiments of Mr *Leibnitz*, who was the firſt that eſtabliſhed a Diſtinction between the moving Force, which is overcome by an Obſtacle, and that which acts againſt a Reſiſtance that gives way. The firſt they call *dead Force*, and they are agreed that it ought to be valued as the Quantity of Motion, by multiplying the Maſs by the ſimple Velocity. As to the laſt, which they call *live Force*, they pretend, that to eſtimate it according to it's juſt Value, the Maſs muſt be multiplied, not by the ſimple Velocity, but by the Square of the Velocity; that is to ſay, by the Velocity multiplyed by itſelf. If, for Example, the Velocity is 3, it is not by 3 that the Maſs muſt be multiplied, but by 9, or three times three. According to this Opinion, a Body which acts againſt an Obſtacle, having it's Maſs 2, and an Impulſe to regulate it's Velocity at 4, has but 8 Degrees of Force while the Reſiſtance remains victorious; but no ſooner does this Reſiſtance come to yield, but the Force to which it is obedient becomes alive, and from 8 mounts to 32.

We may well conclude, that a Philoſopher ſuch as Mr *Leibnitz* was, and ſo great a Mathematician, was not determined raſhly to introduce a Principle of ſuch Novelty, and which appeared to be of ſuch Conſequence in Mechanicks. He has even proclaimed it by a pompous Title, which ſhewed his Confidence in it*. And indeed, he has ſupported his Theory by Experiments, and by ſuch ſpecious Arguments, that we cannot be much ſurprized that he has found Defenders, even among the Philoſophers, the moſt able and the beſt informed. But we cannot but obſerve likewiſe, that the greateſt Number have rejected this new Doctrine, and look upon it as a Paradox. And that after long Examinations, the greateſt Part have been of Opinion, that we muſt rather endeavour to reconcile the Phænomena which ſerve for Proofs of Mr *Leibnitz*'s Notion, with the Principles that are known and generally admitted, than to receive a Novelty which does not ſeem to be connected with thoſe clear and diſtinct Ideas, which we had hitherto of the Motion of Bodies.

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* Brevis Demonſtratio Erroris memorabilis *Carteſii*, et aliorum. Act. Lipſ. 1636. p. 161.

We do not think ourſelves obliged to make a Scrutiny into this Queſtion, in a Work wherein we propoſe only to eſtabliſh ſuch Principles as are the leaſt conteſted. The ſeveral Pieces of this famous Diſpute are better laid open than we can pretend to do, in many Works already printed and well known. I ſhall mention but two, one is the twenty-firſt and laſt Chapter of a Volume in Octavo, printed in 1740, under the Title of *Inſtitutions of Phyſicks*; in which a Lady, as much to be regarded for her Learning as her Birth, has ſet in the beſt Light with the greateſt Ingenuity, whatever can be ſaid in favour of the living Forces. The other is, *A Diſſertation upon the Eſtimation of the moving Forces of Bodies*; in which M. *de Mairan*, who is the Author of it, recites a Memoir, which he had read to the Academy of Sciences, in 1728. In this he oppoſes the Opinion of living Forces by very ſtrong Reaſons; and explains very intelligibly, and upon the common Principles, whatever appeared not to be capable of it, but by admitting the Principle of Mr *Leibnitz*.

However I muſt not omit, (and this is one of the Reaſons, which diſpenſe with me, for not farther inſiſting on this Queſtion) that though the Sentiments are divided about the Manner of valuing the Force of Bodies in Motion, yet they are perfectly agreed about the Produce of theſe Forces, and about the Effects, that will reſult from them. Thoſe who do not receive Mr *Leibnitz*'s Diſtinction, agree however with the Defenders of living Forces, that the Effects are quadruple on the Part of a Body, which moves with two Degrees of Velocity, in Compariſon of that, which has but one. But, ſay they, 'tis not becauſe 4 is the Square of 2, that this Effect follows. 'Tis only becauſe the Body, which has 2 Degrees of Velocity makes an Effort, which is repeated twice as much as that of a Body, which moves with one Degree of Velocity. And it muſt be owned, that if we make the Conſideration of Time to enter into the Examination of the Facts, which are brought, as Proofs of the living Forces; we ſhall then find ourſelves in the common Road; and the Square of the Velocities has no longer a Place for the Eſtimation of Forces, which are only retarded by Reſiſtances, which yield; but to value thoſe, which act againſt invincible Obſtacles.

It follows from this Conceſſion, and from it's Reſtriction, that if the Affair of living Forces be not a Queſtion about a Word only, at leaſt it may be ſaid, that it is not of ſo great Conſequence in Mechanicks, as it ſeemed to be: And that we may eſtimate indifferently, and without any Error in

Practice, the Force of Bodies by the Quantity of Motion, that is, by their Maſs and by their ſimple actual Velocity, if they really move: And, if they are retained by invincible Obſtacles, by their Tendency to Motion, which is as their Maſs and their initial Velocity; that is, the Velocity with which they would begin to move, if the Obſtacle were to give way.

Rest is the State oppoſite to Motion. 'Tis therefore the State of a Body, which perſeveres in the ſame Relations of Situation, with the Objects that ſurround it whether *near* or *a-far off*. I ſay near or a-far off to ſhew, that we are here concerned about abſolute Reſt: And that we do not conſider as ſuch, the State of a Body which is carried away with whatever ſurrounds it; as a Man, who travels with three other Perſons in the ſame Coach. For, though he may be at Reſt relatively, and in Reſpect of thoſe that accompany him; he is not ſo in Reſpect of external Objects.

Yet this Kind of Reſt, which we have now excluded, is perhaps the only one, which we ought to admit, to ſpeak rigorouſly; for if the whole Globe, that we inhabit, turns continually about it's Axis, and at the ſame time deſcribes an Orbit about the Sun, as it is very probable; there is no Body upon it's Surface but what partakes of the Motion, which is common to all it's Parts. And if any thing appears to be at Reſt, 'tis only relatively to other terreſtrial Objects. But as whatever ſurrounds it in this Reſpect is extended as far as our whole Sphere; when we only compare terreſtrial Bodies with one another, we may conſider, as abſolute, the Reſt of that Thing, which does not change it's Situation in reſpect of them.

Rest has not it's Degrees as Motion has, unleſs when we confound it with the Force of Inactivity. It is always as much as it can be. But it may happen, and what is very common, that a Body may be at Reſt if conſidered as a Whole, and yet it's Parts may be in actual Motion. A Block of Marble, which is expoſed to the Heat of the Sun, does not change it's Place, but all it's Parts are in Agitation. For all Naturaliſts agree, that one of the chief Effects of Heat is, to put in Motion the Parts of the Maſs, upon which it acts.

SECTION

SECTION III.

Of the Laws of SIMPLE MOTION.

THE Laws of Motion are certain general Rules, according to which all Bodies are conſtantly moved, when they comply with any moving Force.

Simple Motion is, when a Body complies with one Force only, or which tends but to one Point alone. Such is that of a Man who glides in a Right-Line upon a Canal of Ice: Or that of a heavy Body, which it's own Weight makes to deſcend along a Line perpendicular to the Horizon. Such a Motion is the Effect of a ſingle Impulſe, or of ſeveral, which ſucceed one another in the ſame Direction.

The firſt Law of SIMPLE MOTION.

Every Body, which is once put in Motion, continues to move in the Direction, and with the Degree of Velocity it has received; if it's State is not changed by ſome new Cauſe.

THIS is as much as to ſay, that if the Body departs from the Right-Line which it has once begun to deſcribe; if it's Velocity is either accelerated or retarded; theſe Changes muſt proceed from ſome particular Cauſes, which determine it otherwiſe, which add to, or which retrench from it's Motion, without which the firſt Cauſe would not ceaſe to have it's full Effect. For why ſhould it's State ſuffer any Change? The Force of Inactivity, which kept it at Reſt as long as it could, and which was to be overcome in order to put it in Motion, makes it afterwards reſiſt' any Variation as much as it can. And this Reſiſtance muſt again be overcome by ſome poſitive Force, before we ſhall find any Degree of more or leſs in the State of the Body.

BUT why ſhould Nature make itſelf a Law, which is never to have an Effect? Or rather, How can we aſſign to Bodies in Motion, a Conſtancy of Direction and Velocity, which does not repreſent Nature as ſhe appears to be? Has any one ever ſeen a Motion without Alteration, and which makes itſelf perpetual without a Neceſſity of being renewed? A Body the moſt in Motion, and the moſt violently agitated, does it not at laſt come to Reſt, after ſome determinate Time?

IT muſt be owned that we have not any Experiment in our Power, that can prove in a direct and poſitive Manner, what is declared in this firſt Law of Motion.

BUT firſt we have ſhewn above, that whatever State a Body is in, it endeavours to continue in it, by what we have called the Force of Inactivity. This Principle ſuffices to eſtabliſh the Law in Queſtion; becauſe by abſtracting from all foreign Reſiſtance, when once a Body is in Motion, we can ſee nothing in it to reſiſt the Impulſe it has received, nor that can deſtroy that Inactivity, which withſtands a Change of it's State.

SECONDLY, if it be true that Bodies always loſe their Motion after a certain Time, it is not leſs true, that we always know the Obſtacles, which make them loſe it. And becauſe that inevitable Reſiſtances, (tho' foreign to them) make the Motion of Bodies to ceaſe; would this be a Reaſon to conclude, that Motion is of ſuch a Nature as never to be able to ſtop? Ought we not rather to judge quite the contrary, even upon this very account, that there is abſolute need of poſitive Reſiſtances to make it ſtop? Let us ſee then what theſe Cauſes are, which make Motion to ceaſe; and let us chooſe ſuch by way of Preference, which are ſo connected with the State of Nature, as that they cannot be avoided.

FIRST, In whatever place, or in whatever Manner we make a Body to move, it is always found in ſome Fluid, which in this Reſpect is called a *Medium*, which it is continually obliged to puſh before it, to make itſelf a Paſſage. And as this Medium is material, it gives a continual Reſiſtance to the Body, which endeavours to diſplace it. The Body then cannot continue to move, but by uſing at every Inſtant a Part of it's Motion to overcome this Reſiſtance. Thus after a certain Time it muſt have uſed it all, and find itſelf reduced to a State of Reſt.

SECONDLY, All Bodies being heavy, none of them can move in a Direction different from that, which is proper to it's Gravity, unleſs it is ſuſtained by Suſpenſion, or by a Plain; or that it ſwims in ſome Fluid, which touches it on all Sides. In whatever Manner we conſider it, it muſt always neceſſarily paſs through the different Points of the Surface of the Plain that it deſcribes, or of the Medium that it penetrates; or that the Pieces, which ſuſpend it, ſhall do the ſame thing one over the other. This ſucceſſive Application of Surface to Surface is called *Friction*, and gives Reſiſtance to Motion. For, the Surfaces of Bodies are never perfectly ſmooth. The prominent Parts of one ſink into the Cavities of the other, which makes them glide not without ſome Difficulty.

THE Reſiſtance of Mediums, and that which proceeds from Friction, are Cauſes therefore which will hinder the firſt Law of Motion from having it's due Effect. For, being inevitable in the State of Nature, Reſiſtances will reſult from them, which will indiſpenſably deſtroy a Part of the Velocity of Bodies at every Moment.

No Engine then that we put in Motion can ever exert the whole Motion it has received, upon the Obſtacle we propoſed to overcome; ſince the Cauſes we have now mentioned will neceſſarily conſume a Part of it. As it is of ſome Conſequence to know how much of it is left after this Deduction is made; we ſhall now proceed to lay down here what is chiefly to be conſidered, when we would make an Eſtimate of the Reſiſtances that ariſe from Friction, or from Mediums.

ARTICLE I.

Of the RESISTANCE *of* MEDIUMS.

MEDIUMS, tho' they are fluid, yet they reſiſt like other Bodies by their Inactivity, which ſtruggles againſt being removed out of it's Place. But this Inactivity, as we have ſaid before, is always proportional to the Maſs. All other things being alike, the more Denſity the Medium has, the more Reſiſtance it muſt give.

But the Maſs of Bodies does not depend on their Denſity alone, but alſo on their Magnitude. For, a Pint of Water weighs more than half a Pint of the ſame Water. So that the ſame Medium, in like Circumſtances, reſiſts in Proportion to the Quantity that is diſplaced; and this Quantity ſhould be meaſured by the anterior Surface of the Body in Motion, and by the Space, which we make it paſs through. If I divide the Air or Water by the Palm of my Hand, I ſhall diſplace more at every Inſtant, than if I divided them in an equal time by the Edge of my Hand; and I ſhall alſo find more Reſiſtance.

The Maſs of this Portion of the Medium to be removed, being determined by it's Denſity, and by the Magnitude of the ſolid Surface that puſhes it; it muſt be ſo alſo by the Velocity of the Body. For it is eaſy to conceive, if I make my Hand to move in the Water the Length of two Feet in a Second, I ſhall diſplace a greater Quantity of the Fluid, than if in the ſame Time my Hand had only moved the Space of one Foot. But a greater Quantity of Water makes a greater Maſs, which has a greater Reſiſtance; and the Inactivity has a greater Velocity to oppoſe, as it oppoſed itſelf to the firſt Degree, which we made the yielding Fluid to aſſume. The following Experiments will prove what we have now advanced, concerning the Reſiſtance of Mediums, and will clear up what we have ſaid about them.

EXPERIMENT I.

Preparation.

A kind of a Trough or Tray is divided into two equal Parts, by a Partition, which reaches from End to End; ſo that Water may be put on one Side, and the other Side is left full of Air only. A Pillar with a Bracket on each Side is raiſed from the middle of the Partition, on which are ſuſpended two equal Rods; and at the Ends of theſe are faſtened two Balls of Metal, which are alike both in Weight and Volume, and which when put in Motion may paſs and repaſs, each in it's proper Part of the Veſſel. See *Fig.* 4.

EFFECTS.

THE two Balls depart each at the ſame time, with equal Quantities of Motion; that, which moves in the Water, loſes it's whole Velocity in 4 or 5 Seconds: Whereas the other, whoſe Vibrations are made in that Part of the Trough, which contains only Air, preſerves it's Motion for a long Time, and does not entirely loſe it till after a very great Number of Vibrations.

EXPLANATIONS.

THE two Balls being of the ſame Metal, and having equal Volumes, as is already ſuppoſed, will neceſſarily have equal Maſſes: And when they begin to deſcribe like Arches at the Ends of the two equal Rods, their Velocities are alſo equal, as we ſhall ſhew afterwards. Wherefore ſince their Motion is to be meaſured by their Maſſes and Velocities, the two Balls in our Experiment begin to move with an equal Quantity of Motion. At the firſt Inſtant each of them removes an equal Volume of it's reſpective Fluid. But the Volume of Water removed by F is about 800 Times denſer than the Air diſplaced by G. Theſe two Bodies therefore have exerted their Forces upon very unequal Reſiſtances, ſince they are in the Ratio of 1 to 800 Thus the Ball F could not go on till it had conſumed a Part of it's Force, which is 800 Times greater than what the Ball G loſes of it's Force. And what is done in the firſt Inſtant begins again in the next; and the Velocities of the two Bodies diminiſh in ſuch Manner, that their Difference is nearly proportional to that of the Denſity of the Mediums; till at laſt they are both reduced to a State of Reſt.

APPLICATIONS.

SIR *Iſaac Newton* has demonſtrated, that if a ſpherical Body moves in a Medium at Reſt, the Denſity of which is equal to it's own; it would loſe half it's Motion before it had deſcribed a Space equal in Length to two of it's Diameters. If we do but recollect the Principles before eſtabliſhed, and which we have now confirmed by the foregoing Experiment, we ſhall eaſily conceive how to reduce to an exact Calculation, the Reſiſtance that a Fluid can make to the Motion of a ſolid Body immerſed therein. For, ſuppoſe it to be a Ball of Gold, which moves in Water in a Right-Line; what it diſplaces is equivalent to a Cylinder, the Baſe of which has for the Diameter the ſame as that of the Ball, and for it's

Axis the Line deſcribed by it's Centre. The Denſities of Gold and of Water are known; 'tis alſo known what is the Relation of a Sphere to a Cylinder, of a Diameter and Altitude given. All theſe Quantities being therefore known, we may judge of the Reſiſtance that the Water makes to the Ball, while it deſcribes ſuch or ſuch a Space. And by comparing what it has loſt of it's Velocity to what it had when it began to move, we may judge of what ſtill remains to it.

We have already ſaid, that to eſtimate the Reſiſtance of Fluids, it is neceſſary to have Regard to the Velocity of the moving Body. There is no Medium ſo eaſy to divide, but that it requires ſome determinate Time to give way. We generally find this Time to be very ſhort, becauſe the Velocities we make Uſe of for this Purpoſe are not very great. And the Compariſon that we make of the Time employed againſt them, to that in which they become obedient, makes us embrace this Sentiment. But we change our Minds when we conſider certain Effects which we cannot explain, but in ſuppoſing, that we have not given the Fluid Time to give way. Why, for Inſtance, do the Strokes of the Oars make a Boat go forwards? And why do they not make it go forward ſo much the faſter, the quicker and more frequent they are? 'Tis becauſe when the Water is ſtruck quicker than it can give way, by this Slowneſs of Obedience it becomes the Fulcrum of a Leaver, which the Waterman makes to act. The Fiſh do the ſame thing with their Tails as the Waterman does with his Oars; the Swimmer with his Arms and Legs; and Water-Fowl with their Feet, which for this Purpoſe are formed in a Manner fit to puſh againſt a large Quantity of Water.

EXPERIMENT II.

PREPARATION.

IN *Fig.* 5. HI repreſents a Piece of Clock-Work, the Moderator of which is a Fly with two Wings, 1, 2. The Spring is wound up with a Key, and the Piece K is a Leaver, which moves from left to right, and from right to left, to make the Wheel-Work play, or to ſtop it's Motion. This Inſtrument is ſet upon the Plate of an Air-Pump, which we have repreſented intire in *Fig.* 1. of the ſecond Lecture. Then it is covered with a Glaſs-Receiver, furniſhed above with a Stem of Metal L, which paſſes through a Copper-Ferril, full of greaſy Pieces of Leather, and by which one may move the Leaver K, without letting in the Air, after a *Vacuum* is made in the Receiver. See *Fig.* 6.

EFFECTS.

WHEN the Wheel-Work is made to play in the Vacuum, one may perceive by the Frequency of the Strokes of the Hammers, which ſtrike againſt the

Bell,

Bell, that the Motion of the Wheel-Work is much more free, than when the Receiver is full of Air like to that of the Atmoſphere.

EXPLANATIONS.

WHAT is commonly called *Boyle's Vacuum* is nothing elſe but a Space, wherein the Air is rarified as much as poſſible, by means of a pneumatic Engine, which this *Engliſh* Philoſopher has much improved. But we ſhall make it appear, and all Naturaliſts are agreed in it, that this Vacuum is only a Medium of leſs Denſity, than that in which we ſee the greateſt Part of Bodies to move. In neither of theſe two Mediums, that is in the common Air or in the rarified Air, the Wheel-Work has a compleat Liberty; becauſe independently of theſe other Cauſes, the Fly has always ſome Reſiſtance to overcome, that it may move in the Fluid that ſurrounds it. The Reſiſtance of this Fluid is proportional to it's Denſity. And for this Reaſon, in an Air that is leſs denſe, the Moderator being leſs diſturbed itſelf, gives more Liberty to the Wheels, and therefore procures a greater Frequency of ſtriking to the Hammers.

APPLICATIONS.

WE ſee by this Experiment, that the Air is a reſiſting Medium, and in Regard to Bodies in Motion is as all other Fluids; only being much leſs denſe than the moſt of them, it gives leſs Reſiſtance when other Circumſtances are the ſame. Wherefore to find a Point of Support in it's Reſiſtance, as we have ſeen it is to be found in that of the Water, it muſt be ſtruck with much more Swiftneſs, or elſe a greater Quantity of it muſt be puſhed at the ſame Time. The Birds raiſe themſelves, ſupport themſelves, and make long Flights in the Air, notwithſtanding the Weight of their Bodies, which always conſiderably exceeds that of the Medium in which they are converſant. Thoſe which fly for a long Time, and very far, as the Swallows, the greateſt Part of Birds of Prey, many of the Water-Fowls, *&c.* have generally but little Bodies, many Feathers, and large Wings. On the contrary thoſe of a ſhorter Flight or leſs frequent, have commonly more Fleſh and leſs Wings in Proportion. But, if we take Notice of it, we may obſerve, that theſe beat their Wings oftener than the other in flying. Sparrows, Chaffinches, Goldfinches, Linnets, *&c.* fly as it were by Starts, and do not ſupport themſelves long in the ſame Direction. Their Wings cannot raiſe and ſuſtain their Bodies, but by a Velocity, which they can hardly hold out for many Moments. While they reſt in order to begin again, their own Weight gains upon them, and makes them loſe a Part of that Elevation they had obtained before: So that their Flight is only a Succeſſion of Jerks and Starts.

There are Birds which ſupport themſelves for ſome Time at the ſame Height, without ſeeming to move their Wings, which they call *planing*. We ought to ſuppoſe however that they move them, but that their Vibrations are ſo quick and ſo ſhort; that we cannot perceive them at a certain Diſtance. The great Swiftneſs of this Motion may ſupply for ſome Time, inſtead of thoſe beatings of the Wings which are more diſcernible. And it is alſo obſerved, that the planing Birds are obliged from Time to Time, to regain that Height by a Flight in the common way, which they have inſenſibly loſt, and by ſlower and more extenſive Motions to repoſe, as we may ſay, the Muſcles whoſe Spring has been too much ſtretched, during theſe ſhort and frequent Vibrations.

By this we ſee why Domeſtick Birds, or thoſe which grow very fat at certain Seaſons, fly ſo little and ſo clumſily. As they increaſe in Bulk, their Wings alſo ſhould grow larger, to encompaſs a greater Volume of Air: Or their Strength ſhould increaſe in Proportion, to make them act with more Velocity. But the Degree of Strength, and the Conformation in every Species, are not variable with their Corpulency.

Let us now compare the Weight of a Man, with the Strength which he ought to have in his Arms, to be able to move Wings of an Extent proportioned to his Maſs, with a Velocity capable of ſupporting him in the Air; and then we ſhall ſee how great was the Folly of thoſe, who have been contriving Means to fly, and have looked upon it as a thing poſſible. It is a vain Imagination to think, that nothing is wanting but Dexterity and Exerciſe. It would be eaſy to ſhew, that the Arms of the ſtrongeſt and moſt active Man are not capable of ſuch a continued Effort, as is able to produce ſuch an Effect.

EXPERIMENT III.

PREPARATION.

THE Inſtrument repreſented in *Fig.* 7. is a double Mill, each of which has the ſame Number of Sails, of the ſame Weight, and of the ſame Length and Breadth; only with this Difference, that in one of the two the Plain of every Sail can be inclined to the Axis in any Manner we pleaſe. the ſame Spring, which unbends when we let down a Button to be ſeen at M, equally puſhes againſt two little Broches N, N, which are fixed to the Naves of the Mills. Thus when both comply with this common Impulſe, they begin to move with equal Velocities.

EFFECTS.

IF the Sails of the little Mills are in a like Poſition in Reſpect of their Axes; for Example, if in each the Plain of every Sail is parallel to the common Axis, the Motion impreſſed by the Spring continues equal in both; they make a like Number of Turns, and ceaſe to move at the ſame Time. On the contrary; if in one of the two Mills, the Breadth of the Sails falls upon the Axis at right Angles: or, which is the ſame thing, if their Plains are all found in that of the ſame Circle; then the ſame Impulſe makes this turn much faſter, and for a much longer Time than the other.

EXPLANATIONS.

IN the firſt Caſe of the foregoing Experiment, the ſails of each Mill preſent their Faces to the common Medium, which they muſt diſplace in order to move. They are ſuppoſed not to differ in any Circumſtance, they find then equal Reſiſtances in the ſame Time, conſequently they loſe equal Quantities of Force in the ſame Inſtants. When the Velocity is deſtroyed in one of the Mills, it will alſo be deſtroyed in the other. Quite on the contrary in the ſecond Caſe, one of the two Mills preſents it's Sails edge-wiſe; in this Poſition they are only thin Plates, which eaſily divide the Air, and which find much leſs Reſiſtance from it, ſince the Quantity that is to be removed is much leſs. Therefore that which in equal Times loſes leſs Force, muſt turn ſwifter and much longer than the other.

APPLICATIONS.

THIS laſt Experiment ſhews, that the ſame Maſs may meet with different Reſiſtances in the ſame

Medium, according as it preſents directly to it a greater or a leſſer Surface. The Boatman makes his Oar to act on the flat Side, when he ſeeks a Point of Support in the Reſiſtance of the Water: But he lifts it out by the Edge, that he may have leſs Trouble, when he intends to put himſelf in a Condition to renew his Labour.

'Tis for the ſame Reaſon, that a Body generally preſerves it's Motion better when it is entire, than when it is divided. For Diviſion multiplies Surfaces, and conſequently the Reſiſtance of the Medium. When an Ounce of Lead comes out of a Gun under any Quantity of Surface whatever, the Impulſe of the Powder which determines the Velocity is the ſame. Yet every one knows, that a Bullet is always carried much farther than a like Quantity of Lead in Shot. This Difference proceeds from the Reſiſtance of the Air, which acts in the Ratio of the Surfaces. For every little Grain or Shot, as well as the Bullet, always preſents to the Air, which it divides, half of it's ſpherical Superficies; and the Weights being equal, the Sum of the little hemiſpherical Surfaces of the Shot much exceeds that of one Bullet.

As it often happens, that we do not take ſufficient Notice of the Reſiſtance of the Medium, ſo ſometimes our Prejudices aſcribe more to it than it really has. Who is it that has not heard, for Example, that a Gun diſcharged upon the Water, or from one Side of a River or Pond to the other, will not carry a Bullet ſo far as in another Place? The Reaſon which is given for it, by ſaying that the Vapour from the Water thickens the Air, has ſomething like Truth. But it is imputing too much to it, when we aſcribe ſenſible Effects to this imaginary thickening of the Air. The Experiment aforegoing has ſhewn us, that we cannot conſiderably vary it's Reſiſtance, unleſs we create conſiderable Differences in it's Denſity. And the Tryals that I have often repeated with Care have convinced me, that the Fact in Queſtion is at leaſt an Exaggeration. If any one has apprehended, that being on the Water he could not reach ſuch Objects as elſewhere he might have done, 'tis becauſe he was miſtaken in the Diſtance, which always appears leſs to us when we ſee nothing but an uniform Extent, wherein we find no Objects to aſſiſt us in eſtimating it, ſo that it cannot be ſurprizing if we have failed in killing a Bird at 60 Paces from us, when we imagined it was but 50. Now the Denſity of the Medium, augmented by a Vapour from the Water, could have but little ſhare in this Effect.

HITHERTO we have conſidered the Medium as calm and at Reſt. But if it is agitated, it's Reſiſtance may be encreaſed or diminiſhed by it's own Motion. The Fiſh that ſwims againſt the Current of a River has two Reſiſtances to overcome. One is the Motion of the Water, the Direction of which is contrary to his own. The other is the Inactivity of the Volume of Water anſwering to his own, and which he muſt remove as if it were ſtanding Water. A Man that walks againſt the Wind does the ſame thing.

And it is for this Reaſon, that when we make a Body to move againſt the Direction of a Fluid, the Motion of which is rapid, we diminiſh it's Volume as much as poſſible, that the Strength of the Current may have the leſs Power over it. A Ship that has the Wind againſt it, furls it's Sails. And in a like Caſe, the Waterman makes his Paſſengers to ſit down, while he carries them over a River.

If the Body and the Fluid, which ſerves as a Medium to it, both move in the ſame Direction, either they have equal Velocities, or one has more than the other. In the firſt Caſe the Reſiſtance of the Medium is none at all. Such is the Motion of a Fiſh, which exactly follows the Current of the Water. In the latter Caſe, that of the two which has the moſt Velocity communicates ſome of it to the other, at the Expenſe of that which has it. A Cannon-Ball which is diſcharged in the Direction of the Wind, does not find ſo much Reſiſtance in the Air, as it would in calm Weather. But as it moves ſwifter than the Wind, it muſt always open itſelf a Paſſage in this Medium, which flies before it but with too much Slowneſs. If we know by the Rules before laid down, what would be the Reſiſtance of a Medium which is at Reſt; we may alſo know, what it's Degree of Velocity for or againſt, adds to, or takes away from this Reſiſtance.

ARTICLE II.

Of the RESISTANCE *of* FRICTION *or* ATTRITION.

In order to acquire a juſt Idea of Friction, it ſhould be obſerved, that the Superficies of any Body whatever is never perfectly plain or ſmooth. For tho' we ſhould ſuppoſe, that all the ſolid Parts which compoſe it, are exactly in the ſame Plain, (and when will that be found?) the Pores which ſeparate them, would ſtill oblige us to conceive this Superficies, as an Aſſemblage of little Eminencies and Cavities. Let us ſuppoſe that two Plains of this Kind touch one another through their whole Extent; the prominent Parts of one will enter into the hollow Parts of the other, nearly as it happens to a Cuſhion covered with Velvet, placed upon a Table covered with the ſame. Or, if it be a ſolid Body, which we plunge into a Fluid, this in Conſequence of it's Tenuity and the Fluidity of it's Parts, fills exactly the Cavities of the other, as one may obſerve by the Wetneſs it retains after it is taken out again.

Now we are to conſider, that when we make one Body to run over the Surface of another Body, this may be done in two different Manners, which it is neceſſary well to diſtinguiſh. For firſt we may apply ſucceſſively the ſame Parts of one, to different Parts of the other; as when we make a Book, for Inſtance, to ſlide along a Table. And this we will call a Friction of the firſt Kind. *Secondly*, we may make different Parts of one Surface ſucceſſively to touch the different Parts of the other; as when we make a Ball to roll upon a Billiard-Table. And this we will call a Friction of the ſecond Kind.

In the firſt Caſe the Motion we give to that of the two Bodies, which paſſes over the other, has a Direction perpendicular to that, according to which the Parts of the Surfaces are mutually engaged. For, according to our Suppoſition, the Surface, which we make to ſlide horizontally, is that of a heavy Body, which it's Weight ſupports vertically on the Table. And this Kind of Friction often occaſions the breaking of thoſe little Eminencies, which form the Roughneſs of a Superficies. This may be obſerved by the Duſt, which is produced by two Marbles, or by two Pieces of ſawn Wood, which are rubbed one againſt another with ſome Violence.

In the ſecond Caſe theſe ſame Parts, that are engaged quit one another, almoſt as the Teeth of two Wheels of a Watch, when they roll one over another. If it happens that they quit with Difficulty, 'tis becauſe there is a Diſproportion between the protuberant Parts and the Hollows that receive them. But this laſt Kind of Friction is never ſo powerful as the other, to retard Motion.

THE Cuſtom of dragging the Wheels of Carriages when the Deſcent is too ſteep, furniſhes us with a familiar Example of the different Effects of theſe two Kinds of Friction. When they are afraid that a Coach or Waggon ſhould hurry too faſt down a Hill, they hinder the Wheels from turning round their Axis: Then the ſame Point of the Circumference drags ſucceſſively upon a Number of Points on the Ground. This is a Friction of the firſt Kind, which very conſiderably reſiſts the Motion of the Carriage. It is not ſo when every Wheel turns in the uſual Manner about it's Axis; for then it expoſes it's different Parts to the Plain it is to run over. It's Friction, as to the Circumference, is only one of the ſecond Kind, and it's Motion is much more free; perhaps too much ſo, if it was aſſiſted by too ſteep a Deſcent.

IT is not ſo eaſy to eſtimate the Reſiſtance that proceeds from Attrition, as that of Mediums, conſidered in Reſpect of their Denſity, and of the Volume and Velocity of the Body which removes them. The ſucceſſive Paſſage of one Surface over another is ſo much the more retarded, the more Inequalities each of them have. But this *more* or *leſs* may be varied *ad infinitum*, not only by the Nature of the Bodies, but alſo from the Degree of Perfection they may receive from Art. A Workman can never ſay, that he has poliſhed alike two Pieces of the ſame Wood, or of the ſame Metal, or of the ſame Stone, *&c.* And tho' he had a certain Rule to aſſure himſelf of it, we cannot reckon upon the Continuance of this State. All Matters wear away and change by little and little, and theſe

Accidents, of which hardly any Eſtimation can be made, ſometimes increaſe, but oftener leſſen the Poliſh and Smoothneſs of Surfaces.

THE other Quantities which enter into the Valuation of Friction, ſuch as the Magnitude of Surfaces, the Preſſure they have upon one another, and their Degrees of Velocities, are things that it is more eaſy to meaſure; but as their Value has a Relation to the actual State of the Surfaces, there will always remain much uncertainty in the Eſtimation of the Reſiſtances that reſult therefrom. We muſt commonly be contented with an Approximation, which often is none; by ſuppoſing a third Part of the Power or of the Motion, communicated to a Machine, is made Uſe of to overcome the Attrition. But it is plain that this muſt be underſtood of a Machine in the great, and that it muſt have a great deal of Variety, according to it's Degree of Simplicity, and according to the Perfection of the Pieces that compoſe it.

SOME Philoſophers* have pretended, that the Magnitude of the Surfaces went for nothing in the Friction, and that we need only to take Account of the Degree of Preſſure. ‘ A Body, ſay they, which ‘ has more Breadth than Thickneſs, ought not to ‘ make more Reſiſtance when it is drawn on it's ‘ greateſt Surface, than when it rubs on it's nar‘ roweſt Side. Becauſe the Preſſure which proceeds ‘ from it's Weight being the ſame in either Caſe, if

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* M. *Amonton*'s Hiſt. of the Acad. of Sciences 1699. p. 164. Exp. of M. *de la Hire*. ibid.

‘ in the firſt more Parts are engaged, they are leſs ‘ deeply engaged than in the ſecond.’

THIS way of reaſoning, which would not be concluſive alone, and to which ſeveral others might be oppoſed *, has been ſupported by ſome very ingenious Experiments, which ſeemingly were very favourable to the Opinion here laid down. But in a Matter like this, wherein we cannot draw general Concluſions from particular Inſtances, we muſt be determined by what happens moſt commonly. Repeated Trials have almoſt always proved to me, as likewiſe to Mr *Muſchenbrock* who has made many of this Kind, that the Surfaces muſt be reckoned as ſomething, tho' much leſs than the Preſſures. As to the Ratios of each of them to the Effects, I have found nothing uniform enough, to lay it down as a Foundation of an exact Theory.

BESIDES the Preſſure and the Magnitude of the Surfaces, we ought likewiſe to admit the Velocity into the Valuation of the Friction. For as this Kind of Reſiſtance proceeds from entangled Parts, which muſt either be broken, or which elſe cannot be diſengaged, but by making the Preſſure to give way, which keeps the Surfaces applied to each other; it is plain, that the Sum of the Reſiſtances ought to be ſo much the greater, the more way the rubbing Body has to make in a given Time. For then the entangled Parts muſt be broken in greater Numbers, or muſt diſengage themſelves more frequently.

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* See Hiſt. of Acad. of Sciences, for 1703, p. 108, &c.

But there is a thing here very remarkable, which is, that this Augmentation of Reſiſtance, which proceeds from the Velocity with which the Surfaces rub one another, has it's Limits and Boundaries, beyond which one may accelerate the Motion, without making the Friction become more conſiderable. Thus one may ſay in a Manner, that by increaſing the Cauſe we do not increaſe the Effect; a Paradox which deſerves explaining.

Let us ſuppoſe that D E and F G, *Fig.* 8. repreſent two Surfaces of hard Bodies, of which the inſenſible Inequalities are ſunk into one another; that the Preſſure which joins them, acts according to the Direction A B, perpendicular to that of the Motion, which makes the two Bodies to ſlide upon one another. We ſee plainly that the upper one cannot move in the Direction B C; except it's moſt elevated Parts *e*, *f*, *g*, *h*, diſengage themſelves from the Hollows into which they are ſunk, which cannot be done unleſs the whole Body D E is lifted up, againſt the Effort of it's Preſſure. If this Preſſure is great enough to make the Parts diſengaged to fall into the Cavities, which immediately follow thoſe that have been quitted; that is to ſay, if the Part *e* which came out of 1 ſhould fall into 2, or into 3, *&c.* it is plain that the Effort which was made to raiſe the Body D E, or (which is the ſame thing,) to diſengage the Parts, muſt be repeated as often as there are ſuch little Elevations in the Surface F G. And the farther the rubbing Body ſhall advance in a given Time, upon that to which it is applied, the more theſe riſings and fallings muſt take Place. Thus the Reſiſtance of the Friction increaſes with the Velocity, as long as this Velocity does not hinder the high Parts of one Surface, to lodge themſelves ſucceſſively in the low Parts of the other Surface, in the Manner here explained.

But it may happen, that the Motion which is made according to the Direction B C may be ſo rapid, that when the Protuberances *e*, *f*, *g*, *h*, have been diſengaged, they may be drawn forward a conſiderable Length before the Preſſure has Time to engage them a-new. That the Part *e*, for Example, having quitted 1, or the firſt hollow Part of the Surface F G, inſtead of falling into 2, the next Hollow, it may be tranſported to 3 or 4; and then it is eaſy to conceive, that the rubbing Body D E may run over twice or thrice as much Surface upon F G, yet without having it's Parts more frequently engaged.

The Experiments I ſhall now produce will ſhew, what appears to me of greater Certainty in the Buſineſs of Friction. Firſt, that the firſt Kind of Friction makes much more Reſiſtance to Motion than the ſecond Kind. Secondly, that the Friction increaſes with the Increaſe of the Surfaces, all other things being alike. Thirdly, that Preſſure alſo makes the Reſiſtance of Friction to increaſe, of whatever Kind it may be. Laſtly, that with equal Proportions the Reſiſtance of Friction increaſes more conſiderably by Preſſure than by the Surfaces.

EXPERIMENT I.

PREPARATION.

Fig. 9. repreſents an Inſtrument compoſed (firſt) of four Rollers 1, 2, 3, 4, ſuſpended by very fine Pivots on two double Frames P, P. And (ſecondly) of another Roller greater than the foregoing, the Axis of which O O through it's whole Length is about 2 ½ Lines Diameter, and is terminated by two Steel Pivots, which turn within two Skrews Q Q, boared in their Length, or elſe upon the two Interſections of the two Pair of Rollers. A ſpiral Spring fixt at one End to one of the double Frames, and at the other to the Axis of this laſt Roller, makes it turn alternately both ways. And the Duration of the Motion of the Roller is reckoned by the Number of the Vibrations of the Spring. It is compoſed (thirdly) of a Piece R, which is repreſented by itſelf, *Fig.* 10. which reſts upon the Axis of the Roller, ſometimes by one Surface *s*, ſometimes by the two others *t*, *t*, which are like *s*, at the End of which is faſtened one or more Weights, to increaſe the Preſſure upon the Axis. When the Spring is bent, the Leaver U is brought near, to ſupport one of the Croſs-Bars of the great Roller, that we may be aſſured of the Degree of Tenſion, and to unbend it with Exactneſs.

At firſt the Pivots of the Roller are put into the Holes of the Skrews Q Q, and afterwards they are made to reſt upon the Interſections of the Rollers, without loading the Axis with the Piece R. And in both the Trials care is taken, that the Spring may have an equal Tenſion.

EFFECTS.

The Spring being ſuffered to unwind, if in the firſt Caſe are counted 29 or 30 Vibrations before the Motion Stops entirely; in the ſecond will be counted about 400, each of which continues for near a Second.

EXPLANATIONS.

The foregoing Experiment, conſidered in the two Facts, which they are brought to eſtabliſh, viſibly prove that Attrition, of whatever Sort it may be, deſtroy Motion by a Reſiſtance which differs only according to the Degrees of more or leſs. And they ſhew at the ſame Time, that of the two Kinds of Attrition which we have before diſtinguiſhed, the firſt has much more conſiderable Effects than the other. When the Pivots turn in the hollow Skrews, 'tis a Friction of the firſt Kind; all their cylindrical Surface paſſes ſucceſſively over the lower Part of each of the Holes. On the contrary, when theſe ſame Pivots by their Motion are made to turn the Rollers that bear them up, it will be only a Friction of the ſecond Kind. For then the Circumference of one unfolds itſelf only on the Circumference of the others; the Part which touched before touching no longer the next Moment, and that Part which went before ſerves it now as a Point of Support, or a Fulcrum, to diſengage itſelf in a favourable Direction; as the Tooth of a Wheel, which begins to enter the Pinion, favours the Separation of that which entered before.

APPLICATIONS.

NOTHING is ſo common in Motion as the Effects of Friction. We find it every where, and it may be ſaid in general, that it is the principal Cauſe of the Alterations and Wearing, which we may obſerve in all the Works of Art; and eſpecially in thoſe, of which we make a frequent Uſe. Our Cloaths, Furniture, Trinkets, Inſtruments, *&c.* laſt only for a certain Time, becauſe the Attrition, to which they are continually expoſed, inſenſibly changes their Surfaces and Forms, and make them loſe thoſe Qualities which depend thereon. The hardeſt and moſt ſolid Matters cannot hold out againſt long Service, but will give Marks of Diminution and Diſſolution. A Razor, a Knife, an Axe, ſoon loſe their fine Edge. Even a Plow-ſhare muſt be repaired now and then; and the Horſe, whoſe Foot ſlips upon the paved Stones, leaves there a Mark, which with half an Eye we may perceive to be Parts of his Iron Shoe, which the Friction has left behind. But as nothing in the Univerſe is annihilated, all theſe Particles, thus ſeperated from their Maſſes, are mixed with different Matters, in which they find one another again, when we think leaſt of it. It has been a Surpriſe to very good Natural Philoſophers, to find Iron in Clay, and in the Aſhes of Plants; becauſe they did not enough conſider the prodigious Diviſibility of Metals in general, and in particular the continual Diſperſion which is made of the Parts of this Metal, as well by the Tools which are uſed in the Tillage of the Earth, as by infinite other Uſes, which put it in a Condition of being ſcattered every where. Others that were more attentive to this great and continual Waſte of Iron-Works, have diſcovered this Metal in the Dirt of great Cities, and have imputed to it that black Colour it has, and of which it is very probably the Cauſe. If Gold was in as great plenty as Iron, and if as frequent and extenſive Uſe was made of it, it is not to be doubted but that we ſhould meet with it likewiſe in all Matters, where we ſhould take the pains to look for it. But he that ſhould happen to find it any where, would he have a Right to ſay that he had made Gold? No more, I think, than he who now finds Iron in Aſhes, can boaſt that he has made Iron. Among all thoſe famous Adepts, who have enriched the World by their golden Promiſes; if there was any Gold-Maker who was ſuch in earneſt, 'twas becauſe among that great Variety of Matters that paſſed through his Crucible, there might be found by Chance ſome ſmall Parcell of Gold, which owed nothing more to the Operation of the Artiſt, than to have ſeparated it from thoſe foreign Mixtures in which it lay concealed. To make Gold after this Manner appears to me a very poſſible thing. But I doubt much whether enough could be made, to defray the Charge of the Coals.

If Attrition is hurtful on many Occaſions, ſo there are many others in which it may be uſed to Advantage. The Arts have found out Means to turn to their Profit, even ſuch things as ſeemed to be moſt detrimental to them. A File is nothing elſe but a Surface purpoſely made rough with Points and Edges. The rubbing of it upon the hardeſt Subſtances is a very convenient Method of forming them to one's Mind, by a well managed Diminution of their Volumes. Thus this Tool is of great Uſe in a Multitude of handicraſt Trades. The intelligent Workman, that makes Uſe of it, derives different Advantages from the ſame Means, according to the Modifications he would introduce. To ſave Time he ſometimes uſes a File, the Ruggedneſs of which requires more of his Strength: Sometimes he chuſes one of a finer Cut, to ſoften what the other ſketched out in rough: And at laſt, when even the fineſt of his Files is not yet fine enough, he anoints it with Oil, which retains the Parts of the Metal as they come off; by which Means the little Cavities of the Tool are filled up, ſo that it's Points become ſhorter, and it's Surface not ſo rough.

WHAT we ſay about Files ought to be underſtood of Grindſtones, and all Whetſtones, which differ not ſo much as to the Effect of the Friction, as to their greater Hardneſs.

COMPASSES, and generally all Inſtruments with Joints, which are to remain open or ſhut in different Degrees, have commonly the Property of an equal or regular Friction; and much Time is ſaved in the Uſe of them, when one is not obliged to fix them by any other Means; as when they are ſtopt by a Skrew, or otherwiſe.

THE Reſiſtance of Friction is diminiſhed by dawbing the Surfaces with any Fluid or fat Matter. We rub with Soap the Edges of a Box, the Cover of which ſhuts too cloſe. We oil Hinges to make them play eaſily. They greaſe the Inſide of the Naves of Wheels. Theſe are ſo many Methods of filling up the greater Inequalities of Surfaces, and conſequently of making them more ſlippery, and fitter to ſlide one over another. Beſides, the Parts of theſe Fluids, or of theſe fat Bodies, which are interpoſed, change the Nature of the Friction. They are ſo many little Globules which roll between the Surfaces, ſerve them as a common Vehicle, and do that in little which we ſee done in a more ſenſible Manner, when they put Rollers under a great Stone, or under a Piece of Timber, to tranſport it the more eaſily from Place to Place.

EXPERIMENT II.

Preparation.

The Pivots of the great Roller are made to reſt upon the Interſections of the four leſſer, and the Spring is bent to the ſame Degree as in the foregoing Experiment. Firſt we place the Piece R upon the Axis of the great Roller by one Surface only *s*, and with it's own Weight alone. Then afterwards it is turned back, to make it carry the two Surfaces *t*, *t*, without increaſing the Weight; and in each Caſe the Vibrations are counted.

Effects.

When the Friction is made by one Surface alone, as in the firſt Caſe, there are counted 40 Vibrations. When the rubbing Surface is doubled, as in the ſecond Caſe, there are counted no more than 29 ½; all other things being alike, as is here ſuppoſed.

Explanations.

The Inequality of Surfaces being the firſt Cauſe of Attrition, it is very natural to think, that by increaſing the Extent of the rubbed Body, we muſt alſo increaſe the Number of theſe Inequalities. If any Caſe can be found, in which this does not ſenſibly happen, it will be an Exception, which is undoubtedly due to the particular Diſpoſition of the Superficies; or however when ſo great a Quantity of Motion is applied, that the Reſiſtance of Attrition will not be conſiderable enough to be meaſured, and conſequently to be compared. But as in great Machines, in which the Attrition will be of much greater Conſequence than elſewhere, the Pieces always have their Surfaces rugged enough; we think the Quantity of their Extent is not to be neglected. Yet we ſee by the foregoing Experiment, that the Reſiſtance of Friction, tho' partly depending on the Magnitude of the Surfaces, does not obſerve it in all it's Proportions. In one of the two Caſes mentioned, the Superficies being double, the Friction was not double. And it would be very difficult, to ſay no more, to determine the Relation of theſe Reſiſtances with a given Quantity of Surface.

APPLICATIONS.

FRICTION, conſidered in reſpect of the rubbing Surfaces, retards the Velocity of all Bodies indifferently. We have juſt now proved it in Solids; and we may obſerve every Day, that it is the ſame in reſpect of Fluids and Liquors. Fountains never riſe to the Height they ought, in reſpect of their Quantity of Motion; and Rivers run ſloweſt when the Waters are low.

WATER which is brought through a Pipe, and which ſpouts out into the Air, is every where liable to Friction. The internal immoveable Surface of the Pipe retards it; and when it paſſes into the Air, it ought to be conſidered as moving yet in another Pipe, the Surface of which does not differ from the other, but by the Rarity and Mobility of it's Parts.

THO' the Surface of a large Pipe is greater than that of a narrower, yet it is leſs ſo in Relation to it's Capacity. For it is a thing demonſtrated, that one of two Inches Diameter, (we ſpeak here of round and cylindrical Pipes) contains four times more Water than one, the Diameter of which is but one Inch; and the Circumference of the firſt is but twice as big again as that of the laſt. We ſee by this, that in ſuch Pipes as theſe, the Friction which proceeds from the Surfaces diminiſhes as we increaſe the Capacity. For if the Volume of Water, which is quadruple in the larger, was contained in four Pipes like to the leſſer, it would anſwer to Surfaces, the Sum of which would be double to that which contains it. Experience is entirely agreeable to this Theory. For the more we diminiſh the Capacity of the Pipes in Pumps, Aqueducts, Fountains, *&c.* the more Retardation we find in the Velocity of the Water.

'TIS for the ſame Reaſon, that Rivers are more rapid at the Time when the Waters are out. The Frictions they have to overcome, on account of their

Channels, are then diſtributed to a more conſiderable Maſs, and conſequently they give leſs Oppoſition to the Motion of the Fluid.

EXPERIMENT III.

PREPARATION.

THE Inſtrument being diſpoſed as in the foregoing Experiment, the Piece R is made to reſt upon the Axis of the great Roller by the Surface S, and the little Weight Y is hung to it at X, which doubles the Preſſure.

EFFECTS.

IN this laſt Caſe we ſhall count but 21 Vibrations, tho' the Spring is wound up as in the foregoing Trials.

EXPLANATIONS.

THE Weight which is added increaſing the Preſſure, makes alſo the Friction to increaſe. For the Parts of the Surfaces, which are mutually engaged, will ſink much farther, and give more Reſiſtance to the Motion which endeavours to ſeparate them. We ſee by this laſt Experiment, that a double Preſſure performs more than a Surface increaſed by it's Half. For we have ſeen before, that in making two Surfaces to rub inſtead of one, the Number of Vibrations was diminiſhed but by one fourth Part. And we ſee now, that in making a double Preſſure there are no more than 21 Vibrations inſtead of 40, which is a Diminution of almoſt one Half.

APPLICATIONS.

In great Heats the Motions of Clock-Work are ſenſibly weakened. This Accident, which diſturbs Pendulums and Watches, commonly depends on ſeveral Cauſes which concur to the ſame Effect. There is one to which little Heed is given, which yet deſerves to be reckoned among the others. 'Tis the Friction which increaſes by Preſſure in Proportion as the Pieces grow hot. For it is known, and we ſhall prove it in due time, that Metals as well as all other Matters increaſe their Volumes by Heat, as they decreaſe in Magnitude by Cold; the ſame Cauſe dilating the Plates makes the Holes narrower, and ſwells the Pivots, ſo that by this double Effect, the Friction increaſes by Preſſure, and the Motion is ſo much the more clogged.

A Turner that ſhapes a Piece of Metal between two fixt Points, is ſometimes ſurpriſed to find, that his Piece reſiſts the Motion of the Bow, after he has turned it freely for ſeveral Minutes. 'Tis becauſe the Friction is increaſed by the Preſſure, as the Metal lengthens by heating. And thus the quickeſt and moſt uſual Remedy for this, is to wet it with a little Water to cool it.

The Uſefulneſs of Tongs, Pinchers, and ſuch Kind of Inſtruments, proceeds only from Friction increaſed by a ſtrong Preſſure.

It may not be amiſs to obſerve here, that ſome Machines which perform their Office well enough in little, will not always do the ſame when we come to execute them in the great, tho' we obſerve the ſame Proportions. This generally proceeds from hence, that Attrition in it's increaſe does not follow the Proportion of the Surfaces only, but rather that of the Preſſure, which is often increaſed with the Weight or Solidity of the Pieces. That is, for Example; if in the Model we have reduced all the Dimenſions to an Inch for a Foot, when we conſtruct in great, the Rafter which is 12 Feet long and 6 Inches ſquare, would weigh 1728 times as much as that which repreſents it in little, if it is of the ſame Matter. This Conſideration, which cannot be neglected when we proceed by Principle, ſometimes will make one conclude to the Diſadvantage of a Machine, the Succeſs of which might otherwiſe ſeem to be very ſecure, even from Experience itſelf.

From all that we have now ſaid and proved, concerning the Reſiſtance of Mediums and Friction, we may draw this Concluſion, that in the natural State there can be no mechanical Motion but what is liable to change. Firſt becauſe a Body can move only in

Space, and there is no Place perfectly void of all Matter. Secondly, becauſe a Body, whatever it is, cannot exerciſe it's Motion but upon ſome Surface, or it muſt be hung on ſome fixt Point, about which it is to move. In either of theſe Caſes there will be Friction, either upon the Plain, or at the Point of Suſpenſion, or in the Medium it muſt paſs through. Therefore the Quantity of Motion that will be communicated to it, will neceſſarily be diminiſhed by this two-fold Obſtacle. So that to move perpetually it muſt acquire new Force at every Inſtant, to repair what it muſt neceſſarily loſe. This is contrary to that firſt Law of Motion, which requires, that a Body ſhould conſtantly keep that State into which it has been put, unleſs this State is changed by ſome new Cauſe. Hence it appears to be evidently demonſtrated, that there can be no perpetual mechanical Motion in the natural State of Things, and that thoſe who ſeek it with ſuch Obſtinacy, and multiply Expences in this View, loſe all their Time, Trouble, and Charges.

If any one takes for perpetual the Motion of a Pendulum, which continues it's equal Vibrations by Means of a Spring, or of a Weight, which is to be wound up at the End of a certain Time, or of any other thing of a like Nature; he does not underſtand the State of the Queſtion. For it muſt be underſtood of a Motion once impreſſed, to which nothing muſt be added afterwards, but is ſufficient of itſelf to perpetuate itſelf. The Spring or the Weight, by it's conſtant Effort, continually repairs the Degree of Velocity that is loſt in the foregoing Inſtant, and this Reparation is an Addition to the firſt Motion.

THOSE who ſuffer themſelves to be impoſed on by the Inſpection of a Machine, or by ſome pretended geometrical Demonſtration, on which they ſometimes rely, to evince the Diſcovery of a perpetual Motion, are either the Dupes of Impoſture, or of ſome Paralogiſm, which cannot maintain their ground againſt thoſe who are better inſtructed. The perpetual Motion is the Philoſopher's Stone of Mechanicks. Thoſe that ſplit upon this Rock muſt be meer Novices in this Science. Juſt as an obſtinate Purſuit of the Quadrature of the Circle, or of the grand Operation, declare a Man to be, in the Judgment of the preſent Age, neither a profound Geometrician, nor an able Chemiſt.

LECTURES
IN
Experimental Philoſophy.

LECTURE IV.

Continuation of the Laws of ſimple Motion.

SECTION I.

Of the Cauſes which change the Direction of Motion.

HAVING ſhewn in the laſt Section of my foregoing Lecture, what it is that indiſpenſably diminiſhes the Velocity of a moving Body; it now remains to declare, what are the Cauſes, which change it's Direction, when it does not keep that which it had at firſt. Now to do this in an intelligible Manner, we ſhall begin by ſettling the ſecond and third Law of ſimple Motion, upon which depend moſt of thoſe things, which we have to deliver about this Matter.

The ſecond Law of SIMPLE MOTION.

The Change from more to leſs, or from leſs to more, which happens to the Motion of any Body, is always proportional to the Cauſe which produces it.

In a moving Body, the Maſs of which we ſuppoſe to be conſtant, there can be no Change but of Velocity or Direction. To change either of theſe, ſome poſitive Force is required, which is not in the Body, before the Change, and which it has not the Power to give itſelf. When this Force acts, it can operate only according to it's Quantity; ſo that we may determine it's Value from that of it's Efficacy. As a Pound of Lead in a Scale has no more Efficacy than the Weight of a Pound, we cannot expect that it's Action againſt the other Scale either exceeds or is leſs than the like Weight, if the Scales are true. And, on the contrary, if this laſt Scale is held in Æquilibrio, we may conclude with all Aſſurance, that the Weight on the other Side, which is the Cauſe of it, is equal to one Pound.

The third Law of SIMPLE MOTION.

Reaction is equal to Preſſure.

When a Body in Motion, or which has a Tendency to Motion, acts upon another Body, it compreſſes or ſqueezes it, and reciprocally the latter exerciſes an equal Compreſſure upon it. When I thruſt the End of my Finger againſt an empty Scale, to raiſe a pound Weight in the other Scale, 'tis the ſame thing as if I held the Weight of a Pound upon my Finger to ſuſtain it. Whether a Man on the Bank of a River draws his Boat to Shore with a Rope, or whether he ſits in his Boat, and draws it to the Shore by the Rope there faſtened to a Stake, the ſame Effect will follow. For the Reſiſtance or the Reaction of the fixt Point, is equal to the Action of him that acts againſt it.

Now we will examine how a Body in Motion changes it's Direction, and what Rule it obſerves in this Change.

When a Body in Motion changes it's Direction, 'tis becauſe it is forced to do it by ſome Obſtacle. For according to the firſt Law, it endeavours of itſelf to perſevere in it's preſent State. But this Obſtacle may be either a fluid Matter in which it opens itſelf a Paſſage, or ſome ſolid Body, which oppoſes it's whole Maſs to it, becauſe of the Coheſion of it's Parts. A Stone thrown into the Water repreſents the firſt Caſe to us. A Ball thrown againſt a Wall is an Example of the ſecond.

SECTION I.

Of the Change of DIRECTION, *cauſed by the meeting of ſome fluid* MATTER.

IF the moving Body which we have determined towards ſome certain Point happens to meet ſome fluid Matter, or which is as ſuch in reſpect of itſelf, it only paſſes out of one Medium into another. And commonly theſe Mediums are not equally penetrable by it, either becauſe of the Difference of their Denſities, or for ſome other Cauſe, which we need not examine here. This more or leſs Reſiſtance, which it finds at entering into the new Medium, does not fail to make it quit it's firſt Direction, as often as it enters obliquely. And this Change is called *Refraction*, to give us to underſtand, that the Direction of the Body is as it were broken, at the place where the two Mediums join. Let us make this plain by a Figure, and by ſome Examples.

SUPPOSE a great Baſon full of Water, the Section of which is repreſented by ABCD, *Fig.* 1. and a Pl 12,
Stone or other hard Body E placed in the Air, and

which is directed towards the Surface of the Water, with Velocity ſufficient to make it enter therein, and to make it there continue it's Motion.

For this Effect we can direct the Stone only after two Manners. That is, either according to the perpendicular Line P F, or elſe according to an oblique Line taken between P F and C F. For it is plain if it ſhould follow C F, or a Line parallel to it, it would never enter into the Water, or (which is the ſame thing) it would not change it's Medium. If the Body E comes to the Surface of the Water in the Line P F, it would continue to move according to F P, and ſo it's Direction would not receive any Change.

But if it follows an oblique Line as *e* F, as ſoon as it arrives at F, the Water will become a *refracting Medium* to it. Inſtead of continuing it's Motion according to F G, it will take a new Direction which will be between F G and F A, ſuch for Example as F H. That is to ſay, the Stone, or any moving Body in general, will ſuffer a Refraction, which Refraction will make it withdraw from the Perpendicular F *p*, more than it would have done if it had continued to move according to it's firſt Direction.

The Refraction would have been made the contrary way, if the Body had paſſed out of a more reſiſting Medium, into another which ſhould reſiſt leſs. For Example, if it went out of Water to enter into Air. So that if it had deſcribed the Line H F, it would not go on according to F R, nor in any other between K and C; but the Refraction, which it would ſuffer in F, would determine it to a new Direction between K and P, which would make it incline more towards the Perpendicular PF.

To remove all Doubt about this Perpendicular, which we take here for a Line of Compariſons, when we would expreſs which way the Refraction is made; it is proper to obſerve, that it has nothing in common with the Horizon, but as far as the Surface of the refracting Medium is horizontal, as it happens when it is a Liquid at Reſt. For it is always the Perpendicular to this Surface that we are concerned with, whatever Poſition the Medium may have which cauſes the Refraction. For Example, if inſtead of ſtanding Water, ſuch as we ſuppoſed it to be, we ſhould chooſe that of a Caſcade, or of a River which ſhould have a conſiderable Declivity, in which to throw the Stone; the Perpendicular to which we ſhould refer the Direction of the Motion, as well before as after it's Entrance into the Water, would be a Line inclined to the Horizon. It would be even horizontal, if the refracting Surface were vertical.

THE Refraction therefore depends on two Conditions, without both of which it could not take Place. The firſt is, the Obliquity of Incidence on the Part of the moving Body. The ſecond is, that there muſt be more Reſiſtance in one of the Mediums than in the other. We will firſt prove this to be ſo in Fact; afterwards we will endeavour to ſhew the Cauſe of it.

EXPERIMENT I.

PREPARATION.

THE Machine repreſented in *Fig.* 2. at 2½ Feet above it's Baſe has a little Braſs Pipe I, through which is let fall a Ball of Lead of about an Ounce in Weight, into a Glaſs Veſſel L, which is 12 or 14 Inches high, and at the Bottom of which is ſpread a little Clay or ſoft Wax, of the Thickneſs of an Inch.

THE Ball having ſhewn it's Place by this firſt Fall, the Veſſel L is filled with Water, and then the Ball is let fall a ſecond time.

EFFECTS.

THE Leaden Ball, after this ſecond Fall, will be found in the ſame Place as it had marked out at it's firſt Fall.

EXPLANATIONS.

IT appears by this Experiment, that the Ball of Lead has always preſerved it's firſt Direction, whether it performed it's whole Motion in the Air, or whether it fell partly in the Air, and partly in the Water. For why ſhould it be turned out of it's Direction, if the Obſtacles it met with are always expoſed alike to all it's Parts? Or if the Effort of it's Gravity, which it complied with, had nothing elſe to overcome but Reſiſtances that yielded all together, with the ſame Facility, or which retarded it in equal Quantities? Let us conſider this Ball at different Moments of it's Fall.

FIRST, while it is yet entirely in the Air, this Fluid, which we ſuppoſe at Reſt, and of an uniform Denſity about the moving Body, does nothing but retard it's Velocity. But this Reſiſtance has no Influence on it's Direction, becauſe it acts indifferently on all Sides.

SECONDLY, we may ſay the ſame thing, if we conſider the Ball at the Time that it plunges itſelf into the Water. For the Difficulty that it finds to open itſelf a Paſſage in this Liquid, tho' greater than that which it found in the Air, does not hinder it from going on towards it's Limit, but only from arriving there with as much Velocity, as it would have had in a Medium leſs reſiſting.

LASTLY, if we examine what is done during the Time that the Ball paſſes out of the Air into the Water, and when it is yet partly in one, and partly in the other of theſe two Mediums; we ſhall eaſily conceive, that this Immerſion can alter nothing in it's firſt Direction.

For when the Body M, *Fig.* 3. deſcends along the Line P*p*; all the Parts of the Surface deſcribe Parallels as N T, *n t*, and the Reſiſtance of the Medium is exerciſed upon the whole Hemiſphere N O *n*. When it begins to plunge, the Water reſiſts directly at O. And as it goes on to ſink, the Parts O S, S R, R N, and their correſpondent Parts *o s*, *s r*, *r n*, ſucceſſively partake of the Reſiſtance of the new Medium. But as theſe different Parts from Plains more and more oblique one than the other, from O towards N on each Side, the Reſiſtance of the Water during this partial Immerſion will increaſe by Quantities, which proceed continually decreaſing.

In all this we can perceive no Cauſe which ſhould make the Body M loſe it's firſt Direction. In Conſequence of it's ſpherical Figure, the Obſtacles which it meets at N, R, S, *&c.* are exactly balanced by the Reſiſtances which are oppoſite, at the Parts *n*, *r*, *s*, &c. and this Equilibrium always keeps the Centre M in the Line P*p*. Therefore this Experiment proves, that an Obliquity of Incidence on the Part of the Body, is abſolutely neceſſary for Refraction; ſince without this, it will continue it's Motion according to it's firſt Direction, although it may paſs out of a Medium of leſs Reſiſtance into one of a greater.

Applications.

APPLICATIONS.

A HEAVY Body, which it's own Weight cauſes to fall into the Water, will be found at the Bottom, in a Place which anſwers perpendicularly to that upon the Surface, by which it paſſed when it fell.

BUT firſt, in order to this we muſt ſuppoſe, that the Fluid was at Reſt during the Time of the Fall. For we know, that if a Body falls into a Stream or a Torrent, it is drawn away by the Current, at the ſame Time that it complies with the Force of Gravity. 'Tis for this Reaſon, that Men who are drowned in running Water, are never found over againſt the Place where they fell in.

SECONDLY, the Figure of a Body which ſinks in a Fluid, contributes much, either to make it keep it's firſt Direction, or to loſe it, independently of the Refraction. For this Figure may be ſuch, as to create Inequalities in the Reſiſtances of the ſame Fluid. For Example, if inſtead of making a ſpherical Body fall into Water, ſuch as is ſuppoſed in our Experiment, we ſhould make Uſe of an Hemiſphere, or the like, and it ſhould be directed parallel to it's plain Surface; it follows from the Explanation we have given above, that this latter moving Body, being more ſtopt on one Side than on the other, by the Fluid it ſeparates; becauſe of it's Figure it would not keep it's firſt Direction, but would deſcribe a Curve-Line, tho' in a very uniform Medium.

'Tis a thing which is well confirmed by a frequent but ſimple Experiment: As often as we throw a Body into the Water horizontally, that has an Edge, and is convex on one Side, ſuch as an Oyſter-Shell, or any other like thing; we never ſee it follow the Direction that has been given it; And if the Convexity is turned downwards, we ſhall often obſerve, that it riſes into the Air, notwithſtanding the Propenſity of it's own Weight.

We may alſo obſerve, that heavy Birds, ſuch as Crows, Pidgeons, *&c.* when they light on the ground after a long Flight, they never fail to bend their Wings and their Tail, to give themſelves a convex Figure below. This neceſſarily directs them in a Curve, which is much lengthened, and which breaks their Fall. On the contrary the ſame Birds, when they are young, light in a heavy Manner, and often hit themſelves againſt the Ground; becauſe they deſcend by a Line which is leſs inclined to the Horizon; either becauſe they are yet unſkilled to take a Figure which may give them another Direction, or becauſe their Feathers are as yet too ſhort, or their Limbs are too weak to allow them to do otherwiſe.

EXPERIMENT II.

PREPARATION.

A B C, *Fig.* 4. is a Quarter of a Circle, or a Quadrant, to which is fixt the Barrel of a Gun upon the Radius A B, and which is faſtened to a Wall, or to ſomething immovable, yet ſo as that it may turn about the Point B. At 18 or 20 Feet Diſtance is a Trough or Bathing-Tub, of the Length of 4 or 5 Feet, and full of Water, the Surface of which is covered with a Piece of fine Gawſe ſtretched out, or with large Sheets of Paper, F is a Frame covered with Gawſe or Paper, which is about 18 Inches high, and 1 Foot wide. This Frame is erected perpendicularly to the Surface of the Water, and it's Baſe D E, which is a pretty heavy Board, is placed upon the Edges of the Trough, at a ſufficient Diſtance from it's Extremity G. Care muſt be taken to cover the leſſer End G of the Trough with a thick ſmooth Deal-Board, to ſecure it from Accidents, and upon which the Mark of a Ball may be perceived. Laſtly when every thing is thus diſpoſed, the Gun is charged with a ſufficient Quantity of Gun-Powder, and likewiſe with a Bullet of Lead which may fit the Barrel as near as poſſible. It is then directed towards the Point I, ſo that it may make an Angle of about 30 or 40 Degrees with the Surface of the Water. Then it is diſcharged with a Piece of Match fixt at *a*. See the Figure.

EFFECTS.

AFTER the Ball has pierced through the two Pieces of Gawſe at I and K, inſtead of continuing it's Motion in this Direction to come to L, it will hit the Deal-Board at H, according to a Line which will make an Angle with the firſt Direction in coming from A to K. This is eaſily ſeen by letting out the Water of the Trough, and then placing the Eye at I. For one may obſerve, that the Point H is ſenſibly above the firſt Direction; and that the Refraction it has ſuffered at the Point K, by entering into the Water, has made it withdraw from the Perpendicular P *p*, more than it would have done if it had continued to move directly to L.

EXPLANATIONS.

'TIS a Conſequence of the Laws of Motion, that a Body will always incline to that Side where it finds the leaſt Reſiſtance. For the Effect being proportional to it's Cauſe, a Body that meets two Obſtacles at the ſame Time, muſt ſuffer more from that which is the ſtronger, and likewiſe more eaſily overcome that which is the weaker. But to overcome an

Obſtacle more eaſily, is to beat it back a certain Quantity in leſs Time, or to beat it back more in a determinate Time. For whatever the Obſtacle may be, it never ſenſibly gives way in an indiviſible Inſtant. The weakeſt therefore is that which ſuffers itſelf to be overcome in a ſhorter Time.

THE Air and the Water, through which the Bullet in our Experiment has paſſed ſucceſſively, one after another have been Obſtacles to it's Motion. But as long as it was entirely in one or in the other of theſe two Mediums, the Reſiſtance being equally diſtributed to all the Parts of the anterior Hemiſphere, as we have ſhewn in our Explanation of the foregoing Experiment, it's Direction could undergo no Change. The Obſtacles, or the reſiſting Parts of the Fluid making an Equilibrium on all Sides, it muſt conſtantly perſevere in the Line A K, and afterwards in the Line K H.

IF the Equality of the Obſtacles againſt all the Parts of the anterior Hemiſphere *n o p*, *Fig*. 5. keep the Body *m* in it's Direction, as long as it continues in one and the ſame Medium; it is plain that in paſſing obliquely out of Air into Water, this ſame Hemiſphere, during the whole Time of it's Immerſion, meets with Obſtacles that are harder to overcome on one Side of it's Surface than on the other. The Point R, for Example, coming to touch the Water, finds more Reſiſtance than the Point Q, which as yet meets only the Air. So that the Equilibrium between the Obſtacles on each Side being now broken, the Center M inclines on the weaker

Side, and begins to forſake it's firſt Direction S T. But as the Difference between the Reſiſtance of Water and that of Air, depends chiefly on the Time to be employed in repelling each of theſe two Fluids, this Difference will increaſe in Proportion as the Velocity of the Body decreaſes. For if the Bullet were to repel the Air and the Water with an infinite Velocity, their Reſiſtances being then nothing, or infinitely ſmall, there would be no Difference between them.

THEREFORE the Motion of the Body M growing more and more languid, by immerging into the Water, muſt feel the Effect of this increaſed Difference, between the Reſiſtance that is made in the Part O R P, and that which acts againſt O Q N. So that the Centre M muſt more and more forſake it's firſt Direction, and deſcend through a ſmall Curve-Line, the laſt Element of which begins the new Direction U X, which the Bullet follows after it's total Immerſion.

APPLICATIONS.

THE foregoing Experiment leads us naturally to an Obſervation, which may be of ſome Uſe to thoſe who are deſirous to kill Fiſh in the Water, by ſhooting them with a Gun. However good Markſmen they may be, they would often fail of their Game, if they had no regard to the Refraction which the Bullet muſt ſuffer, at it's Entrance into the Water. What we have ſhewn above, proves that they muſt ſhoot lower than the Object; becauſe the Bullet always riſes in the Water, when we ſhoot obliquely. 'Tis true, as we cannot ſhoot but at a ſmall Depth, becauſe of the great Reſiſtance of the Water; and as the Weight of the Lead, when the Velocity is weakened, deſtroys a Part of the Refraction by making it ſink; and as beſides the Object has ſome Extent, which it is intended to hit; it ſeems in Practice as if this Change of Direction, which the Bullet meets with at entering the Water, is a Matter of ſmall Importance, and ſo may be neglected. But we ſhould conſider this, that the Fiſh we would ſhoot is ſeen only by the Rays of Light, which proceed from it to us, which paſs obliquely out of Water into Air, and which therefore being in a State of Refraction, do not repreſent the Object to us in it's true Place. Add to this (which is more neceſſary to be obſerved) that the Refraction of Light is made a contrary way to that of other Bodies, as we ſhall ſhew when we treat of Opticks: So that the apparent Place of a Fiſh is higher than it's real Place. And this gives new Strength to the Reaſon before given, of ſhooting lower, tho' we had no Regard to the Refraction of the Bullet.

THO' Refractions are more commonly obſerved in fluid Mediums, yet we may ſay in general, that they take Place in all Bodies, even in thoſe that are ſolid, when the Body that penetrates them, meets obliquely with Layers of Matter, which are more reſiſting one than another. It happens very often, for Example, that when we would bore a Board with a Bodkin, or with a ſmall and flexible Needle, that the Iron bends, and will not follow the Direction we ſtrive to give it. 'Tis becauſe the Point has met obliquely with Parts that are harder one than another; as is eaſy to obſerve in Deal, wherein this Kind of Refractions are often met with. For we often find Difficulty enough to drive a Nail in it to one's Mind, eſpecially if it be long and ſmall.

REFRACTION is ſuſceptible of all Degrees of more and leſs. We have ſeen that it is nothing, when the Direction of the moving Body is perpendicular to the Surface of the refracting Medium. It begins with the Obliquity of Incidence, and increaſes as that increaſes in the ſame Proportion. For the Ball which falls along S T, *Fig.* 5. ſuffers leſs Refraction than that which is directed according to *s t*. And if we recollect what has been ſaid, to give a Rationale of Refraction in general, we ſhall eaſily perceive, even from the Inſpection of the Figure alone, that the Cauſe of this Effect increaſes in Proportion as the Immerſion becomes more oblique. For it is plain, the more the Direction is inclined to the Surface of the Water, the longer Time the Part O R N of the anterior Hemiſphere is in the Air; and conſequently, the Reſiſtance made by the Water on the Part O R P, will have ſo much the more Advantage over that, which acts againſt the correſponding Points O Q N.

OQN

BUT in whatever Degree we conſider the Refraction, we ſhall always find it proportional to the Incidence of the Body, when the Mediums continue the ſame. And we may judge of it by comparing the Angles of Incidence A C P and B F D, *Fig.* 6. with thoſe of Refraction *a* C *p* and *b* F *d*, which are meaſured by the Lines PA, *a p*, which are the Sines thereof. For if P A is to *a p*, as 2 is to 3, the two ſimilar Lines D B and *d b*, which repreſent the Caſe of a greater Degree of Refraction, have ſtill the ſame Ratio to each other.

We muſt not undertake to prove this by Experiments; for the Difficulty of directing heavy Bodies in Lines that are perfectly ſtrait, and oblique to the natural Direction of their Gravity, will not ſuffer us to do it. We ſhall find a convenient Place to do ſomething of this Kind, when we come to treat of Light, which is without the Inconvenience abovementioned.

We ſhall only add, and we ſhall prove it in Fact, that when the Incidence arrives at a certain Point of Obliquity, the Refraction will be made out of the refracting Medium, and which will then be called Reflexion. So that, for Example, a Stone or a leaden Bullet, inſtead of paſſing out of Air into Water, as we have ſeen before, ſhall raiſe itſelf up, after having touched the Surface, and form with it almoſt the ſame Angle as it made in falling. See *Fig.* 7.

EXPERIMENT III.

PREPARATION.

THE Quadrant of *Fig.* 4. muſt be diſpoſed in ſuch Manner, that the Gun-Barrel and Line of Direction M N (*Fig.* 7.) muſt make with the Surface of the Water N P an Angle of about 5 Degrees; and at the other End of the Trough muſt be placed a Plank of ſoft Wood S, which muſt ſtand perpendicular to the the Surface of the Water, and preſent it's Face length-wiſe to the Trough. Alſo a Frame of Gawſe muſt be placed perpendicular to the Surface of the Water, of about a Foot in Length. The Gun being charged as before muſt be fired off.

EFFECTS.

THE Bullet being come to N, inſtead of entering into the Water, and there ſuffering a Refraction as before, it rebounds from the Point of Contact, and goes on to the Plank at S; making it's Angle of Reflexion O N S nearly equal to that of Incidence M N P.

EXPLANATIONS.

EXPLANATIONS.

IN explaining the Cauſes of Refraction above, we have ſhewn, that the Reſiſtance of the Medium againſt a Ball that moves in a Right-Line, is exerted upon half of the ſpherical Surface N O *n*, *Fig.* 3. We have alſo ſhewn in explaining the ſecond Experiment, that when this Hemiſphere comes to touch two Mediums at the ſame Time, one of which reſiſts more than the other, the whole Body, of which it is a Part, inclines moſt on that Side which is weakeſt. Whence it follows, that this Deviation muſt be ſo much the greater, as the reſiſting Fluids differ more from one another, and that the weakeſt of the two poſſeſſes the greateſt Part of the Hemiſphere P R O Q N, *Fig.* 5. The Reſiſtance of the Air is very ſmall, or continues but a ſhort Time in Compariſon of that of the Water. And when the Bullet is directed according to a Line much inclined, as it is in our Experiment; one may eaſily ſee by the Figure, that the Part which anſwers to the Air, is much greater than that which touches the Water. Thus the Exceſs of Reſiſtance on the Part of this latter Medium becomes as a fixt Point, which refuſes Paſſage to the Body for ſome Time, enough to give it Opportunity to continue it's Motion in the Air, which gives way to it very readily.

HITHERTO we ſee plainly enough, why the Bullet does not enter into the Water, and why it finiſhes it's Motion in the Air, after having touched the more reſiſting Medium by a very oblique Direction. But it muſt be allowed, that what has been ſaid is not ſufficient to ſhew, what it is that determines it to riſe upwards by another oblique Direction, which is found in the ſame Plain as that of it's Incidence. For tho' it muſt finiſh it's Motion in the Air, it does not follow from thence that it ſhould be obliged to raiſe itſelf up again, after having once deſcended. If there were no Cauſe to produce this Effect, we could only expect to ſee the Ball ſlide or roll upon the Surface of the Water, when it had once got to it, and that it continued to have ſufficient Velocity to render the Effect of it's Gravity inſenſible. In a Word, all that the Reſiſtance of the Water can do, is to hinder the Body from paſſing through it. But while we conſider in it only an invincible Obſtacle, we do not ſee how it can determine that Body to mount, which at the Point of Context ſeems to have a Propenſity to deſcend. There is therefore ſomething farther to be conſidered, whether it be in the Water that reflects, or in the Ball which ſuffers this Reflexion, or elſe in both of them, relatively to the Circumſtances in which they are found in our Experiment. But as what paſſes here at the meeting of a fluid Surface, in the Caſe of a very oblique Incidence, happens always when a Body falls upon a ſolid Plain at all Inclinations whatever; we ſhall forbear to examine the Cauſe of it, till we ſpeak of reflected Motion in the following Section. It is enough for us to Mention at preſent, that there may be ſuch an Obliquity of Incidence, as that the Surface of the Water may have the ſame Effect in Reſpect of a Ball of Lead, or any other hard Body, as if it were a ſolid and impenetrable Plain.

APPLICATIONS.

THE Experiment we have now explained, may ſerve as a Caution to thoſe who ſhoot into the Water. If they do not ſhoot at a near Diſtance, or from ſome Eminence, the Direction of the Ball may become too oblique, and therefore may not enter the Water at all. So that a Perſon who ſhould think himſelf very ſafe on the oppoſite Side of the River, may yet run a Riſque of being hurt. And it will always be a prudent Precaution, not to ſtand in the Plain of Reflexion. In a Sea-Fight how many Cannon-Balls may be ſeen to riſe again, after they have touched the Sea, and do that by a reflected Motion, which they failed of doing by their firſt Direction?

BUT without going ſo far for ſuch terrible Examples, a Sport among Children, which every Body knows by the Name of *Ducks and Drakes*, will ſhew us the ſame thing with leſs Danger. A Stone that is a little ſharp at the Edges, and thicker in the Middle, if it is ſkimed very obliquely on the Surface of the Water, will riſe again at the Point of Contact, for Reaſons which we have already produced. And if it has received a ſufficient Quantity of Motion, and it's own Weight ſhall determine it a-new to an oblique Incidence, it gives Occaſion to a new Reflexion; and this will often be repeated five or ſix Times ſucceſſively.

SOME Experiments which I have made with Care, but which I have not yet had Opportunity to make in great Work, or not ſufficient to eſtabliſh an exact and circumſtantial Theory, have already confirmed me in the Opinion I had entertained, that the Surface of the Water does not begin to reflect under the ſame Angle, or at a like Obliquity with that of Incidence, all Sorts of Bodies indifferently. I have obſerved, that a Ball of 6 Lines Diameter entered into the Water, when it's Direction made an Angle of 6 Degrees with the Surface; when a larger Ball at the ſame Incidence was reflected. And I doubt not but that Cannon-Balls would do the ſame under a much greater Angle; and that this varies as the Diameters of the Balls vary. The Reſiſtance of the Water is ſo much the greater, as the Parts ſtruck againſt are in a greater Number. When a ſpherical Body falls upon it's Surface, and comes to touch it with a conſiderable Motion; we are not to think it is done in one Point only, but always in a Segment, which Segment finds ſo much the more Reſiſtance, as it makes a Part of a greater Sphere. For having greater Extent with leſs Convexity, it ſtrikes more directly, and a greater Number of the Parts of the Water.

AFTER having now examined the Changes which happen to the Direction of a moving Body, when it meets an Obſtacle which it can penetrate, or in which it can continue it's Motion; let us now ſee what may happen to the ſame Body, when the Obſtacle is a ſolid Body, which refuſes it a Paſſage through it.

SECTION II.

Of Reflected MOTION.

IN the foregoing Section we ſuppoſed, that the Obſtacle which endeavoured to change the Direction of the Body in Motion, was a Matter which it could penetrate, and in which it was able to continue it's Motion for ſome conſiderable Space, ſo as to give Means to obſerve whether it complied with a new Determination. Now we ſuppoſe the Obſtacle to be invincible, an impenetrable Maſs which it cannot remove, nor open itſelf a Way to paſs farther. I ſay, *to paſs farther*; for as there is no Matter which is perfectly hard, and of which the Parts will not yield to a ſufficient Force, when one Body ſtrikes againſt another; when even this laſt cannot be diſplaced becauſe of it's Magnitude, there is always made ſome Hollowneſs or Sinking at the Place of Contact. And if this Sinking is ſuch, as that the Body can inſinuate itſelf into the Maſs; as when a Cannon-Ball enters the Ground, or when a Muſket Bullet is diſcharged into Sand, or a Heap of Snow; then the Obſtacle thus penetrated becomes a new Medium, and if there is any Refraction, it will be performed according to the Laws already eſtabliſhed.

THE Obſtacle, or the Body that is ſtruck, being ſuch then as we here ſuppoſe, immoveable as to it's whole Maſs, but flexible as to it's Parts; the Queſtion is to know, How the moving Body will be directed after the Stroke.

BUT before we anſwer this Queſtion, it will be neceſſary to examine, Whether the Body that ſtrikes will continue it's Motion? For if it is to ſtop without farther Motion, it would be in vain to ſeek for it's Direction. And there are a good many Caſes, in which the Obſtacle will reduce it to Reſt, without reſtoring any Part of what it will loſe.

TO fix our Ideas, let us conceive a Ball of Steel to be thrown againſt a Wall. And for the greater Simplicity, let us look upon the ſtriking Body as perfectly hard, and only conſider the Flexibility of the Body that is ſtruck. In the firſt Inſtant of Contact the Ball will exert, againſt a very ſmall Space of the Stone which it hits, an Effort which will be as it's Maſs and it's actual Velocity. This ſmall Number of Parts, thus compreſſed by the Steel, will yield to it's Motion, and retire back upon the Parts that are neareſt, and thoſe upon the next. The Stone thus condenſes in this Place, and a little ſinking is made. But this Effect is not produced with a Velocity equal to that which the Body had at the Moment it began to touch; for that which was diſplaced made ſome Reſiſtance, and every Reſiſtance (tho' at laſt overcome) deſtroys a Part of the Force which made it give way. Thus at the End of the firſt Inſtant the Ball of Steel will be retarded, and it's Effort at the Beginning of the ſecond Inſtant will be leſs than it was at the firſt.

Now as the Parts that were ſtruck during the firſt Inſtant retired backwards, their Sinking or Introceſſion has given Way for the Ball to touch the Stone according to a larger Surface. The Body therefore will loſe more of it's Velocity during the ſecond Inſtant than the firſt. Firſt, becauſe it will have more Particles to repel; and ſecondly becauſe thoſe of the Medium which were driven in before, reſiſt more than they could do during the firſt Inſtant. For then the Matter ſtruck was leſs condenſed, and the ſtriking Body had more Motion.

We ſee by the Examination of theſe two Inſtants, that the Steel Ball, in penetrating into the Stone or Rock, muſt diminiſh in it's Velocity by Quantities which go on always increaſing; ſince the Parts that receive it's Effort multiply at every Inſtant; and finding themſelves more and more ſupported by thoſe behind them, their common Reſiſtance increaſes at leaſt in the Ratio of theſe two Cauſes.

THE Velocity of the Body may be retarded either uniformly or not. This Diminution cannot hinder it from perſevering in it's firſt Direction, as long as it has any Motion at all. So that the Cavity which is made in the Stone will not be compleat till the Ball ceaſes to move. And, on the contrary, we may conclude, that the Ball is reduced to a State of Reſt, when the Parts of the Stone retire no longer. So that if no new Cauſe is then found, to communicate Motion to the Ball; as it has intirely conſumed what it had received at it's firſt Determination, we ſee it cannot move any longer. And indeed Experiment ſhews us, that it moves no more. For if the Part of the Wall which is expoſed to the Stroke, is ſoft Stone or Plaſter, the Ball remains in the Hole it has made, or elſe it falls back by it's own Weight, if nothing hinders it.

BUT it is not ſo if the Obſtacle it meets with is a hard Stone. We ſhall then ſee it rebound after the Stroke, and a different way from it's firſt Direction. This is called *reflected* Motion. We will ſee then what is the Cauſe of it, and what are the Laws by which it is governed.

IN the Stone, as well as in the Plaſter, there is made during the Stroke a Hollowneſs or Sinking, which only differs according to more or leſs. But when the Obſtacle is elaſtick, ſo that the Parts drove in have the Power of reſtoring themſelves, in the Place and in the Order they had before they were

diſplaced;

diſplaced; it is eaſy to ſee why the ſtriking Body begins to move again, and what determines it to a Direction different from that it had before. For the Parts forced in, by reſtoring themſelves again drive back the Body before them, and give it the ſame Direction they themſelves have.

Now all elaſtick Bodies are not equally ſo; and we may affirm, that we know none that are perfectly ſo. Yet we will ſuppoſe them ſuch at preſent, to make our Theory the more ſimple; and we will firſt conſider the direct Stroke, that is to ſay, that of a moving Body directed perpendicularly againſt the Surface of the Obſtacle.

SUPPOSING the Obſtacle DE, *Fig.* 8. to be a Body of which the Elaſticity is perfect; the Point of Contact A, drove on to B by the Effort of the Body C, ought to return back from B to A, with a Velocity equal to that with which it was diſplaced. The Body C, which it drives before it, deſcribes the ſame Space in the ſame Time. And when by this Reaction it is become again a Tangent to the Surface DE, it finds the ſame Degree of Motion to go from A to F, as it had when paſſing from F to A, it began to make the Cavity *d*B*e*. Thus an Obſtacle, whoſe Elaſticity is perfect, would reſtore to the Body, by a compleat Reaction, all the Motion it had deprived it of, during the Time of the Compreſſion. We are now to regulate the Direction of this reflected Motion.

IN explaining Refraction we have ſhewn above, that when the Body M (*Fig.* 3.) falls perpendicularly upon a refracting Medium, it does not leave the Line of it's firſt Direction, and that as well after, as before the Immerſion, it tends to the ſame Form. Becauſe all the Parts of it's anterior Hemiſphere are equally ſuſtained by the Reſiſtance of the Fluid; and that there is no Cauſe that can favour or abate it's Motion more on one Side than on the other. For a like Reaſon, if the Surface D E is ſolid and perfectly elaſtick, the Body which comes from F to A, after having made the ſinking *d* B *e*, will be ſent back in the ſame Line exactly, and towards the Point F; becauſe the correſponding Parts G, H, comply with Reactions that are perfectly like, the Equilibrium of which neceſſarily keeps the Center C in a Line, the Terms of which are A, F.

We have before proved (ſee *Fig.* 5.) that in the Caſe of oblique Immerſion, the Body forſakes it's firſt Direction; and we have ſhewn the Cauſe of it, in the Inequality of Reſiſtances, which act upon the Points P, R, O, Q, N, duing the Time that this Hemiſphere is plunged into the refracting Medium. We have alſo obſerved, that in this Deviation of the Body cauſed by Retardments, which go on always increaſing till it is plunged, the Centre M deſcribes a little Curve M V.

The ſame thing happens, and for like Reaſons, when a ſpherical Body falls obliquely upon a ſolid and elaſtick Plain, *Fig.* 9. The Parts drove in are ſo many little Springs, which have been bent by the Effort of the moving Body, and which ſlacken it's Velocity more and more, till at laſt it has conſumed all the Motion it had, when it began to touch the Surface of the Plain in I. Thence proceeds the little Curve *i l*, deſcribed by the Centre of the Body. And it is manifeſt, that if this Plain (ſo drove in) were to End at the Point L, the Ball would eſcape by the Line L M, and conſequently it's Centre would deſcribe the Parallel *l m*.

BUT during the Time of it's being thus forced in, as it touches the Plain according to a Surface, and not in a Point; and as all the Springs which it has bent, will unbend themſelves ſucceſſively, and according to the Order in which they have been compreſſed; a double Effect will proceed from hence. Firſt, it reaſſumes it's firſt degree of Motion, becauſe it is repelled by as much Force as compreſſed it. Secondly, it will aſcend again by a Curve M P, *Fig.* 10 like to that which it followed in making it's Cavity; becauſe the Springs it has bent will unbend themſelves againſt it's poſterior Part, and give it a Velocity which is accelerated from M to P; juſt as that which it had at firſt was retarded from I to M. Thus as the Extremity I of the Line of it's Incidence was the beginning of the firſt Curve, ſo that of it's Reflexion P Q is the Continuation of the ſecond. And after this Manner the Angle R M Q will become equal to S M T.

THE Equality of the Angles of Incidence and Reflexion may be demonſtrated in a more geometrical Manner, if we admit a Principle which will be proved afterwards, when we come to ſpeak of compound Motion. That is, that the Body which deſcribes the

Line T M does the ſame as if it had been influenced by two Powers, one of which would have given it a Velocity neceſſary for deſcribing the Line TV, while the other ſhould make it deſcend from the Height TS. When it is arrived at M, if any Cauſe whatſoever ſhould annihilate it's Motion downwards, without diminiſhing that which urges it horizontally; it is evident that in a Time equal to that which it takes up in coming from T to M, it will go from M to R, being no longer influenced but by a ſingle Power. But inſtead of this Suppoſition, when the Body is at M, if the Power that urged it downwards ſhould all of a ſudden be converted into another equal Force, which urges it to move upwards, it will doubtleſs aſcend along M Q, with the ſame Degree of Velocity with which it deſcended along T M. But we have ſeen before, how of theſe two Motions, of which the oblique Incidence is compoſed, that which is perpendicular to the Plain is annulled in the moving Body, and is changed in a like Degree into an other, which is oppoſite in the ſame Line.

HITHERTO we have ſuppoſed the moving Body to be inflexible, and we have only conſidered the Elaſticity of the reflecting Plain. But it is eaſy to conceive, that the ſame Effects muſt take Place, if the Plain is perfectly hard, and the Ball is an elaſtick Body. For in the Stroke it would grow flat, and the Parts beat in, by reſtoring themſelves, would be ſupported by the Plain, and would repel the Body with the ſame Velocity, with which they had been compreſſed, and in the contrary way.

INDEED neither of theſe two Suppoſitions are exactly conformable to Nature. For as we know no Bodies that are endued with perfect Elaſticity, ſo we know none that are quite deprived of it. So that whenever there is a Reflexion, we may affirm, that both the moving Body and the Obſtacle have their Share in it, according to their Degree of Elaſticity.

IT may alſo happen, that a third Body, ſqueezed between each of them at the Time of the Shock, may have ſome Share in the reflected Motion, by performing the Office of a Spring, which one way unbends againſt the Obſtacle, and the other way againſt the moving Body. And then whether the Incidence be direct or oblique, we may expect all that has been hitherto explained, when we ſuppoſed only the Obſtacle or the Body ſtruck, to be elaſtick.

• IT appeats then, that the Things moſt neceſſary to be known, concerning reflected Motion, may be reduced to theſe two Heads. Firſt, that Elaſticity is a neceſſary Cauſe of Reflexion. Secondly, that the Direction of reflected Motion is ſuch, that the Angle of Reflexion is equal to that of the Incidence of the moving Body, when the Reaction is perfect.

THO' theſe two Propoſitions cannot be proved by Experiments that are rigorouſly exact, becauſe we know no Body endued with perfect Elaſticity, or that has none at all; and beſides the Gravity of the moving Body, and the Reſiſtance of the Air will hinder ſome Part of the Effects; yet we may ſhew nearly what ought to be, by ſhewing what is. We ſhall take Care to obſerve, when any thing foreign mingles itſelf with the Facts; and the Remainder will repreſent to us ſufficiently what has been now taught.

EXPERIMENT I.

PREPARATION.

THE Machine which is repreſented by *Fig.* 11. ought to be placed in ſuch a Manner, that it's Baſe ſhall be in an horizontal Plain. A B is a Ciſtern of about an Inch deep, which is filled with Clay mixt with fine Sand, in ſuch Quantity as to be very ſoft, and yet not too clammy. This Ciſtern or Tray can move upon a Hinge, which is at A, and may be fixt at any Degree of Inclination required, by Means of a Claſp and a Skrew at A. C is a little Braſs Pipe fixt to a running Spring, which ſlides in an open Groove in the Arm of the Frame, through which a leaden Ball may paſs, which is fitted to it.

EFFECTS.

WHEN the Leaden Ball is dropt through the little Pipe C, whether it comes perpendicularly to the Surface of the Ciſtern, or whether the Ciſtern preſents itſelf obliquely to the falling Ball, it makes a ſinking in the ſoft Earth, and the Ball there loſes it's whole Motion.

EXPLANATIONS.

WHEN the falling Ball begins to touch the ſoft Earth, it has then a certain Quantity of Motion. 'Tis at the Expenſe of this Motion, that it diſplaces a Portion of this ſoft Matter. It muſt then ceaſe to move, when the Parts it meets at Reſt in it's Direction have been removed ſo far off, as the Quantity of it's Effort required. And it cannot ceaſe ſooner, becauſe a Body in Motion cannot be reduced to a State of Reſt, but by an Obſtacle, the Reſiſtance of which is equal to the whole Quantity of it's Force.

WHETHER a Ball falls perpendicularly upon a Plain inclined to the Horizon, as in one of the two foregoing Experiments; or whether it comes by an oblique Line againſt an horizontal Plain, as is repreſented in *Fig*. 12. 'tis juſt the ſame thing as to the Effect that will follow. And if the Plain is flexible, and without Elaſticity, as we ſuppoſe it to be, the Motion of the Ball muſt be entirely deſtroyed therein, as well as in the foregoing Caſe. For the oblique Direction makes no Change in what we have ſaid about the perpendicular Fall. At moſt it can only cauſe a little Refraction, which we may neglect, becauſe we ſuppoſe the ſinking to be but little conſiderable. But it has nothing of itſelf, which can raiſe

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the moving Body above the Plain, which it has once approached to.

APPLICATIONS.

BODIES without Elaſticity, or which have it but very imperfectly, are fitter than others to ſubdue violent Efforts; becauſe they retard the Velocity of the Body by Degrees, and reduce it to Reſt by yielding from more to leſs. To underſtand this well we may conſider, that there is no Motion, however quick it may be, but takes up a determinate Time. Thus when the Body M, *Fig.* 13. deſcends along the Line D E, to make Room for it's Hemiſphere in the ſoft Earth; tho' to Senſe this Effect may ſeem to be performed in an indiviſible Inſtant, yet we may conceive the Time of this ſinking to be divided (as it were) into ſeveral equal Moments, during which the Body exerts it's Force againſt the yielding Particles. But this Force diminiſhes at every Inſtant, and it diminiſhes by Quantities which increaſe much faſter than the Times. For at the ſecond Moment, the Reſiſtances are in much greater Number than in the firſt; becauſe the Hemiſphere (being farther ſunk) will preſent a greater Surface to the ſoft Earth, which it muſt repel: And the Parts already compreſſed, make a greater Struggle againſt being removed. We may therefore conſider the three Spaces D, F, E, as the Reſults of three equal Moments, during which the Body M has ſpent it's whole Velocity in deſcribing the Line D E.

All Obſtacles which thus give way, partake of the Effort of the moving Body, and ſtop (as it were at ſeveral Times) a Force which could not fail of ſurmounting them, if their whole Action was contracted into a ſhorter Time. For could a Drum, for Inſtance, withſtand the Force of one Stroke, which ſhould be equal to the Sum of all the Strokes, impreſſed by the Sticks in an Hour's Time? An Oaken Plank cannot ſtop the Force of a Muſket-Ball, which a Sack of Wool would deaden in a ſhort Time.

'Tis for a like Reaſon, that we are not hurt by the Fall of a hard Body, which we receive within our Hands, provided the Hand yields for ſome Moments, and does not ſtiffen itſelf againſt it. We ſhould run a Hazard of breaking the Rope, when we ſtop a Boat carried away by the Stream of a River, if we had not the Caution to let it run out by little and little, and ſo overcome the Jirk by degrees.

EXPERIMENT II.

Preparation.

We make Uſe of the ſame Machine for this Experiment, which ſerved for the foregoing, and is repreſented by *Fig.* 11. But inſtead of the Ciſtern filled with ſoft Earth, we put there a Slab of black Marble well poliſhed, and dawbed over with a ſlight

Coat of Oil; and the Ball made to fall through the little braſs Pipe is of Ivory.

EFFECTS.

WHEN the Ivory Ball is let fall perpendicularly upon the Marble, after having touched the Plain, it rebounds by the ſame Line along which it fell; but not ſo high as the Place from whence it fell. And we may perceive upon the Marble a round Spot, which is about a Line in Diameter.

EXPLANATIONS.

WHAT we have ſaid above, in diſcuſſing the Queſtion about reflected Motion, will ſuffice to explain the Fact now related. The Spot found upon the Marble, proves evidently that in the Shock there was a Compreſſion of Parts in one of the two Bodies, and probably in both, as we have ſhewn when we treated of Elaſticity. And after the Experiment ended, as we find the Surfaces in the ſame Condition they were in before the Contact, it is plain they have reſtored themſelves. And we have ſhewn, that this Reſtoration, if it were perfect, would be ſufficient to give back to the Body all the Motion it had ſpent, in following it's firſt Direction, but the contrary way. If this Effect has not it's full Force, 'tis becauſe the Reſiſtance of the Air oppoſes it in ſome meaſure;

and there is good Reaſon to think, that neither the Ivory, nor the Marble, reſtore themſelves with the ſame Velocity, with which they are compreſſed.

APPLICATION.

AN elaſtick Body, that has been compreſſed, and then permitted to reſtore itſelf, does not return to it's firſt State, till after a certain Number of reciprocal Motions called *Vibrations*, which are eaſily perceived in a Plate of Steel, in the String of a Harpſichord, in a Branch of a Tree, and ſuch like; which has been bent, and then left to itſelf. This Motion, which brings back the elaſtick Body beyond it's Place of Reſt, proceeds from hence, that the compreſſed Part in reſtoring itſelf, takes again the ſame Degree of Velocity, which it had received at the firſt Inſtant of the Shock, and the contrary way, as we have before explained. Let us take for an Example a String of a Viol, or of a Harpſichord, *Fig.* 14. ſtretched between two fixt Points G, H; againſt this we make a ſolid Body to ſtrike, with a Quantity of Motion ſufficient to bring it from the Point I to the Point K. This Percuſſion lengthens the String; for it is plain the Sum of the two Lengths G K and H K is greater than GH. If it can freely reſtore itſelf, it's Spring will bring back the Point K to I, and then it will have, in the Direction I L, a Velocity equal to that which the Percuſſion had given it to go to K. This Velocity muſt have it's Effect; it will tranſport the Point I towards L, until ſufficient Reſiſtances will finally make it ceaſe. Now if the middle of the String moves in this Manner, the Parts that compoſe it on each Side muſt be lengthened, and their Reſiſtance will more and more weaken this Motion. It will end at laſt, when the whole Velocity of Reaction is ſpent. And it is eaſy to ſee, that in returning from K to I, if the String is found to have the ſame Degree of Velocity that it had received by the Stroke, to deſcend to K, the Line I L ought to become equal to I K. If the Elaſticity was perfect, and theſe Vibrations were performed in a Medium that had no Reſiſtance, theſe Sorts of Motions would be perpetual. For when the String is arrived at L by virtue of it's Reaction, it has the ſame degree of Tenſion which it had when it was ſtretched at the Point K; and conſequently it would have the Force neceſſary to return thither at the ſecond Vibration. We may ſay as much of the third, and of others *ad infinitum.* But the Reaction being never compleat, for the Reaſons mentioned before, the ſecond Vibration has leſs Extent then the firſt, and the third ſtill leſs than the ſecond; and theſe Diminutions at laſt reduce the String to it's firſt Condition.

I HAVE taken a String as an Example, in order to make this Explanation the more ſenſible; but we ſhould conceive, that the ſame thing happens to all elaſtick Bodies, except a Difference of more or leſs, according to the Figure and Rigidity of the Parts. Thus the Parchment of a Drum becomes alternately concave and convex; and the Ball of Ivory which fell upon the Marble, did not reſume it's ſpherical Figure, till after having been for ſome Time an Ellipſoid, of which the greateſt Diameter is ſucceſſively both horizontal and vertical. *Fig.* 15.

'Tis a Thing remarkable, that the ſame Spring makes all it's Vibrations iſochronal, that is, performed in equal Times, whether they are ſmall or great. And we had then an Opportunity of ſeeing the Proof of it, when we ſhewed the Uſe of the Machine, *Fig.* 9. of *Lecture* 3. with which we meaſured the Degrees of Friction. For by comparing the Vibrations of the ſpiral Spring, with the Oſcillations of a Pendulum that vibrates Seconds, we ſhall very eaſily obſerve, that the firſt and the thirtieth (for Inſtance) are performed in Times that to Senſe are equal.

It is farther to be obſerved, that diſtended Springs reſtore themſelves with ſo much the more Velocity, as more Force is required to bend them. Thus tho' two thin Plates ſhould be equally elaſtick, if one of the two is more flexible than the other, it will make Vibrations that will have leſs Extent, but which will be more frequent; which we ſhall ſhew hereafter, when we come to ſpeak of Sounds.

EXPERIMENT III.

Preparation.

For this Experiment we ſhall make uſe of the Machine, *Fig.* 11. which ſerved for the foregoing.

But inſtead of putting the marble Slab or Table in an horizontal Situation, we ſhall now make it incline, as the Line AD. And we advance the little Pipe C in it's Groove, ſo that it may be directly over the Point E.

EFFECTS.

IF the Ivory Ball falls upon the marble Table according to the Line NE, it will proceed along EF, and lodge itſelf in an Opening made in the Piece G, the Breadth of which is equal to the Diameter of the Ball. And on the Surface of the Marble may be obſerved a Spot, not perfectly round as in the foregoing Experiment, but a little oblong, and ſituated in ſuch manner, as that it's greateſt Diameter will be in the Plain of Reflexion.

EXPLANATIONS.

WE have ſufficiently explained the Cauſes of Reflected Motion, and Experiment ſhews us, that the Angle of Reflection AEF is nearly equal to that of Incidence HED. Therefore I need not ſo much inſiſt on proving the Equality of theſe Angles, as in ſhewing why the Angle of Reflexion is not ſtrictly and rigorouſly equal to the other. There are three Cauſes that concur to make it ſomething leſſer. Firſt, the Ball that ſtrikes, and the Plain that reflects it, have not a perfect Elaſticity; therefore the Reaction is not compleat. Secondly, the Air that muſt be divided to paſs from E to F, retards a little the Velocity of the Body. It is therefore a longer Time in it's Paſſage than it ought to be, and this Retardation gives Occaſion for the Admiſſion of a third Cauſe. For thirdly, Gravity acts upon the Ball as it deſcribes the Line EF or EG, and impels it downwards. Therefore inſtead of deſcribing an exact right Line, it arrives at G by a curve Line, the Extremity of which is a little lower than the Direction of it's Reflected Motion would require.

BUT tho' the Equality of theſe Angles cannot take Place in the natural State, yet cannot we perceive even through theſe Obſtacles, that it is nevertheleſs an eſtabliſhed Rule in Nature, and founded upon Laws that are generally acknowledged?

THE little oblong Spot that we ſee upon the Marble after the Contact, is a clear Proof that a Ball which ſtrikes an Obſtacle obliquely, penetrates it by a curve Line, as we have ſaid above; and that it comes out of this Cavity by a like Line. Thus the longer Diameter of the oblong Spot is repreſented by the Line *pi*. *Fig.* 10.

APPLICATIONS.

THE Games of Billards and Tennis, are almoſt entirely founded on the Rule we have now explained and proved. In one of them there is a ſpherical Body, which is commonly ſtruck againſt a Plain, according to an oblique or perpendicular Direction. In the other it is the Plain itſelf which is preſented to the

Body, under different Angles of Inclination. And the principal thing in each, is to eſtimate well the reflected Motion by the Angle of Incidence.

When a Cannon-Ball diſcharged horizontally, comes to touch the Ground, it rebounds ſeveral times ſucceſſively; and it's Marks are obſerved upon the Ground, which are much longer than they are wide or deep. 'Tis the Bullet that grazes and mounts again, as the Ball in our Experiment, obſerving two Curves which join together at the laſt Degree of ſinking, where the Reflexion commences. And as it's Velocity downwards, is much leſs than it's horizontal Motion; it deſcribes a very great Length, in the ſame Time that it deſcends to a very little Depth. And hence proceeds that great Difference that is obſerved in theſe two Dimenſions, when the Traces we ſpeak of are examined.

SECTION III.

Of the Communication of MOTION *in the Colliſion of* BODIES.

ALTHOUGH the ſolid Obſtacles, which ſtop or which reflect moving Bodies, have their Effects only in virtue of the Motion, which is communicated to them by the Body; and that this Communication is made according to the Rules that we ſhall eſtabliſh in this Section; yet we have thought proper to treat ſeparately of this Action of Bodies, conſidered in the Caſe wherein the Body ſtruck, lets us perceive the Marks of the Percuſſion it ſuffers, by a ſenſible Removal of it's whole Volume. That is to ſay, that after having taught what happens to a Body in Motion, as well in Reſpect of it's Velocity, as of it's Direction, in relation to an immoveable Obſtacle, or which is conſidered as ſuch; we ſhall now examine the Changes, of which both of them (the Velocity and Direction) are ſuſceptible, when the Obſtacle is removed by the Impulſe, or at leaſt may be ſo. And that we may proceed from what is more ſimple, to what is compound, we ſhall firſt conſider the Effects of Percuſſion in ſoft Bodies, wherein Reaction cannot take Place, in order to go on afterwards to the Colliſion of elaſtick Bodies.

We always ſuppoſe, in order to make our Theory more ſimple and eaſier to be apprehended; firſt, that the Bodies which ſtrike, are endued with a perfect Elaſticity, or elſe have none at all. Secondly, that their Motions are performed in a Medium without Reſiſtance, and without Friction. So that the Doctrine we are going to deliver would be falſe, if the Facts exhibited ſhould be found to be exactly repreſented by the Experiments. For the Hindrances, from whence we make Abſtraction, muſt neceſſarily have ſome Influence upon the Reſults. So that our Proofs ought not to paſs for concluſive, but when they ſhall appear to produce ſomething leſs than what might have been expected. Thus, for Example, if the Body A, coming to ſtrike the Body B, *Fig.* 16. ſhould make upon it the whole Impreſſion it is able, in virtue of the Motion it has at parting from the Point *a*; it would then do too much, becauſe beſides this it muſt overcome the Friction, the Reſiſtance of the Medium, *&c.* It would therefore exert upon the Body B, which is the laſt Obſtacle it has to overcome, only the Force which remains to it, after having ſurmounted the others. And if we make no Reckoning of what it will have loſt in overcoming thoſe others, we cannot expect a compleat Effect, when the Percuſſion is performed at *b*.

We ſhall here only conſider the direct Colliſion, that is, ſuch as is made by two Bodies, whoſe Centres of Gravity are found in the Direction of their Motions, as in *Fig.* 16. And to make the Execution more eaſy, we will make all our Experiments with ſpherical Bodies, which we will ſuſpend on very fine Threads, *Fig.* 20. that we may diminiſh the Frictions, and the Reſiſtance of the Air, as much as poſſible. And as we ſhall often have Occaſion to know the Degree of Velocity of theſe little Globes; we will keep them ſuſpended upon fixt Points, about which they may deſcribe Arches of Circles, which may be meaſured by Graduations, *Fig.* 21. What ſhall be afterwards taught concerning Gravity, will let us know, how by the Length of theſe Arches we may regulate the Velocity of the Bodies which deſcribe them. This is a Method which has been ſucceſsfully uſed by many able Philoſophers, and eſpecially by Mr *Mariotte*. The Machine I make Uſe of, and which is repreſented by *Fig.* 17. is the ſame as his, which I have rendered more convenient, and extended to other Uſes.

Before the Appulſe of two Bodies, there is a Space between them to be paſſed over, either by one of the two entirely, or partly by one, and partly by the other; otherwiſe there could be no Colliſion. This Space cannot be paſſed over but in a certain Time, and the Duration of this Time, meaſures the *relative Velocity* of theſe two Bodies. That is to ſay, the Velocity with which the Diſtance diminiſhes, whether one of the two continues at Reſt, or whether they both move the ſame way, or contrary ways, with equal, greater, or leſs Velocity than one another. So that if the two Bodies A, B, *Fig.* 16. at the Diſtance of 4 Feet, are joined together in a Second, the relative Velocity is the ſame, whether B alone deſcribes the whole Space, or whether he meets A coming towards him at the ſecond or third Foot, *&c.* provided that the Motion by which one approaches to the other, is performed in a Second. Therefore this relative Velocity muſt not be confounded with the *abſolute Velocity*, or the proper Velocity of each of the moving Bodies. For we ſee, by this Example, that this may vary in ſuch Caſes as the other would not change at all.

THE Relative Velocity being given, we muſt ſtill conſider the Maſſes. For the Body ſtruck, oppoſes it's Inactivity to the ſtriking Body, and we have ſeen elſewhere, that this kind of Reſiſtance is meaſured by the Quantity of Matter contained and connected together under the ſame Volume. Therefore we ought to expect, that in the Colliſion, a great Maſs will receive leſs Velocity than a ſmaller. And to make the ſame Body acquire more Motion, more alſo muſt be given to the Body which is to communicate it. Becauſe the Inactivity not only reſiſts Motion, but alſo a greater Degree of Motion; as we have proved elſewhere.

WHEN we mentioned Motion in general, we always forbore to examine into the Nature of this Kind of Being, or rather of Modification, becauſe this Kind of Queſtions belongs more to Metaphyſicks than to

Experimental Philoſophy. For the very ſame Reaſon we ſhall not amuſe ourſelves to examine how Velocity paſſes from one Body into another. We ſhall confine ourſelves, to ſuch Facts as can be made manifeſt; and in running through the more general Caſes, we ſhall ſettle, by way of Experiment, ſuch Propoſitions as may be conſidered as Principles or Laws, to which we may reduce other Effects more particular, as ſo many Conſequences.

ARTICLE I.

Of the COLLISION *of* BODIES *that are not elaſtick.*

PROPOSITION I.

When a Body at Reſt is ſtruck by another Body, the Velocity of the ſtriking Body ought to be divided between both, according to the Ratio of their Maſſes.

That is to ſay, that after the Shock the two Bodies will continue to move according to the Direction of the ſtriking Body; and that the Velocity of this being diminiſhed by the Reſiſtance of the other, the Remainder which is common to both will be ſo much the leſs, as the Body which is ſtruck ſhall have more Maſs.

Thus the Body at Reſt being ſtruck by a Maſs equal to it's own, the Velocity after the Stroke will be reduced to one half.

There will remain two Thirds of the Velocity, if the ſtriking Body is double to the other.

If it is the Body ſtruck which is double in Bulk to the other, the Velocity, after the Stroke, will be but a third Part of what it had before. We will bring theſe three Caſes to a Trial.

EXPERIMENT I.

Preparation.

The Machine which is repreſented by *Fig.* 17. being diſpoſed in ſuch Manner, that the Plum-Line may be parallel to the Line A B; that the two Threads of Suſpenſion C D and E F may ſuſtain in one and the ſame Line, and at the ſame Height, the Centres of the two Balls of ſoft Earth, each of which weighs two Ounces; and in ſuch Manner that being at Reſt, their Surfaces may touch in a Point; that the firſt Graduation of each of the two moveable Rulers G and H may be over againſt each of the Threads; and laſtly that the little Runner or Index L, may be placed a little before the third Graduation of the Ruler G, and the other Index M over againſt the ſixth of the other Ruler H.

EFFECTS.

THE Ball F being removed to M, and then left to fall of itſelf by it's own Weight, will ſtrike the other Ball D. Each of them are flattened alike at the Place of Contact, and, after the Stroke, both of them move the ſame way, and the Thread, that ſuſpends the Ball D, goes to the Index L.

EXPLANATIONS.

WHEN the Ball F falls along an Arch of ſix Graduations, if it found no Obſtacle, it would aſcend along an equal Arch on the other Side. Of this we may be aſſured by taking the Ball D out of it's way; and we ſhall explain the Reaſon of it, when we come to treat of the Phænomena of Gravity. So that when it comes to F from the Point M, it's Motion is then ſuch, that it can raiſe it's Maſs of two Ounces into an Arch of ſix Graduations. But a Force, which can tranſport a Maſs of two Ounces to ſix Degrees Diſtance in a given Time, can tranſport a Maſs as big again but half that Diſtance in the ſame Time. But when the Ball F meets the Ball D, which does not ſuffer it to paſs farther without carrying it along with it; 'tis a Velocity of 6 Degrees applied to a Maſs of 4 Ounces: and both together will ceaſe to move, after having deſcribed only 3 Graduations, as the Experiment ſhews.

At the Time of the Shock the flattening is made in both the Balls, and in the preſent Caſe this flattening is equal in both; which two Facts deſerve to be obſerved and explained.

We have ſaid already, that nothing in Nature is performed with Preciſion, and *per ſaltum*. And the Effects that are moſt quick, and to our Senſes appear to be almoſt inſtantaneous, are always produced in a finite Time, that is to ſay, in a Time the Duration of which is not the ſhorteſt that we can conceive. When the two Balls begin to touch, the more advanced Parts of the ſtriking Ball have already loſt a Part of their Velocity, whilſt the Centre and the more remote Parts ſtill retain theirs. Therefore 'tis not till after ſome Inſtants are paſt, (very ſhort ones indeed) that this lingring Maſs aſſumes a Velocity equally retarded in all it's Parts. But if the Parts of a Body are moved ſome quicker than others, their relative Poſition, or (which is the ſame) the Figure of the Body muſt be changed. The flattening therefore of the Ball F is an Effect, and alſo a Proof, of the Velocity being exceſſively retarded at different Times.

The ſame thing may be ſaid of the Ball that is ſtruck. It does not paſs from it's State of Reſt, to three Degrees of Velocity all at once. The Parts that are immediately expoſed to the Shock are moved ſooner, and quicker, than the Centre and the farther Hemiſphere. And theſe ſucceſſive Removals create an Introceſſion of Matter, which changes the Figure of the whole.

Now theſe flattenings in each of the Balls are cauſed by their Inactivity, which oppoſes any Change of State in both; and this Force of Inactivity is equal to the Maſs. So that in the Shock of two Bodies, of the ſame Matter and of equal Weight, the flattenings in each ought to be equal.

EXPERIMENT II.

PREPARATION.

THE Ball D is made of 4 Ounces, and the Ball F of 2 Ounces. The firſt remains at Reſt, and 6 Degrees of Velocity is given to the other. Other things are diſpoſed as in the foregoing Experiment.

EFFECTS.

AFTER the Impulſe the two Balls continue to touch one another, and deſcribe together two Graduations; and the flattening of each is greater than in the foregoing Caſe.

EXPLANATIONS.

THE Ball F by deſcending from 6 Graduations receives 6 Degrees of Velocity; that is to ſay, it can carry it's own Weight the Space of ſix Graduations on the contrary Side. But this Weight being encreaſed by two thirds more, by the meeting of the Ball D, which it carries along with it, it's Force now is ſufficient only for one third Part of the Space which it would have deſcribed, if nothing had ſtood in it's way.

As to the flattening, it ought to be ſo much the greater, the longer Time the Body ſtruck reſiſts it's Removal: Since it is this Reſiſtance, as we have ſaid before, which interrupts the Uniformity of the Velocity in the Parts of each Ball. But in the preſent Caſe the Ball D reſiſts as much again as a Ball of 2 Ounces would do. Therefore there was Room for the ſinking of a greater Number of Parts.

EXPERIMENT III.

PREPARATION.

IN this Experiment we proceed as in the two others, except only that we give to the Ball D which is at Reſt, 2 Ounces of Matter, and to the Ball F 4 Ounces, which we make to move with 6 Degrees of Velocity.

EFFECTS.

THE two Bodies being united after the Shock, deſcribe 4 Graduations, and the flattenings are not ſo ſtrong as in the two foregoing Caſes.

EXPLANATIONS.

WHAT we have ſaid to explain the two foregoing Experiments, may ſuffice to give an Account of this. We muſt always conſider the two Balls after the Percuſſion as making but one Maſs. And we ſhould conſider alſo, that 6 Degrees of Force, which can tranſport a Maſs of 4 Ounces a Space of 6 Graduations, cannot tranſport one of 6 ounces ſo far. If the Reſiſtance of 4 Ounces can conſume the whole Force in deſcribing this Space, an Augmentation to the Weight of one third, ought alſo to diminiſh the Space by one third. And conſequently, inſtead of 6 Graduations which the Ball F would have deſcribed alone, and without an Obſtacle, being joined to the Ball D, which it has put into Motion, it can now deſcribe but 4.

BUT as the Ball D, which weighs but 2 Ounces, reſiſts leſs than when it weighs 4 or 3, it has afforded leſs Occaſion to the ſinking of it's Parts; and on the other hand it has leſs retarded the anterior Parts of the Ball F. For we may eaſily conceive, that if all of a ſudden, and in an indiviſible Inſtant, it ſhould aſſume the whole Velocity which is communicated to it, there could be no flattening on either Side. For it would fly away before the Ball F at the very Inſtant of Contact, with a Velocity equal to that of the ſtriking Body; which would make it eſcape from it's Action or Influence.

APPLICATIONS.

SINCE in the Percuſſion, wherein one of the two Bodies is at Reſt, the Velocity of the ſtriking Body diminiſhes in Proportion to the Maſs of the Body ſtruck, we muſt draw from thence this Conſequence; that the Motion muſt be inſenſible after the Shock, if the Body at Reſt is infinitely greater than that which ſtrikes it. And it is doubtleſs for this Reaſon, that a Cannon Ball ſeems to have loſt all it's Motion, when it is ſhot againſt a Rampart, or againſt a ſtrong Caſtle. For the Velocity which remains to it after the Stroke, is to that which it communicates, as it's Maſs is to that of the Obſtacle it ſtrikes; that is, as an infinitely little Quantity, to one that is infinitely great.

'TIS alſo in conſequence of this Principle, that it is often ſaid, the greateſt Bulk is always removed (tho' infinitely little) by the Percuſſion of the ſmalleſt Body. But I cannot ſee why we are obliged to admit this Propoſition, as a neceſſary Conſequence from the Law we have now eſtabliſhed, except we ſuppoſe the Body ſtruck to be perfectly inflexible. Otherwiſe let it be never ſo great, it's Reſiſtance will be at a ſufficient Duration to conſume all the ſenſible Velocity of the moving Body, by the Introceſſion of the Parts, which will be occaſioned by the Impulſe.

THE Experiments now alledged will alſo inform us, why all Bodies in general are broke, or ſooner loſe their Figure, by ſtriking againſt Obſtacles that are immoveable, than when they meet with ſuch as may be moved. A Veſſel will ſplit againſt a Rock, but may be unhurt by hitting againſt another Veſſel at Reſt. 'Tis becauſe the Rock giving way but little or nothing to the Motion of the Veſſel, the Parts of this which begin the Conflict have already loſt all their Velocity, while the others have ſtill all theirs. Therefore a Change of Figure is made; the Pieces are ſtrained and break, if the Shock is violent enough. Whereas if the Veſſel had met a floating Body which would comply with it's Impulſe, the Parts expoſed to the Shock would not be entirely ſtopt, and the others are retarded by little and little as well as themſelves.

WORKMEN that labour at the Hammer, ſay that it makes a falſe Stroke, when the Matter they are at work upon ſlips from them, whether it be becauſe it is not ſufficiently ſupported, or becauſe the Tool is ill directed. And the Smith juſtly complains if his Anvil is too light, or if it is ſupported by a Block that is unſteady. For then the Iron that he is at work upon yielding with it's Point of Support, his Stroke has not it's full Effect, as it would have had if his Anvil had been better fixt, and had kept the Side of the Iron which touches it at perfect Reſt, while he ſtrikes the other Side with his Hammer.

THE Play of Mall or Racket, has ſo much Relation to our firſt Propoſition, about the Percuſſion of Bodies, and to the Experiments we have made Uſe of in proving it, that it is almoſt needleſs to make any Application of it here. If we attend to it ever ſo little we ſhall ſoon ſee, upon what the Proportions are founded, which ſhould be obſerved between the Maſs of the Racket and the Ball. How one, by Means of a long Handle, receives from the Player a very great Velocity; why, and in what Proportion, a Part of this Velocity is communicated to the other, *&c.*

PROPOSITION II.

WHEN two Bodies moving the ſame way with unequal Velocities ſtrike one another, whether their Maſſes are equal or not, they will continue to move together in their firſt Direction with a common Velocity, which will be leſs than that of the ſtriking Body, but greater than that of the Body ſtruck before the Percuſſion.

As ſoon as we ſuppoſe that the two Bodies move the ſame way, it follows neceſſarily, that which precedes muſt not move ſo faſt as that which follows, otherwiſe there can be no Colliſion. For if both moved with equal Velocities, it is plain they could not approach to each other. When that which moves ſwifteſt overtakes the ſlower, it's Slowneſs makes an Obſtacle to the other. But this Obſtacle is in Motion, and muſt divide the Exceſs of the Velocity of the ſtriking Body in the Ratio of it's Maſs; as has been proved before. The following Experiments will ſhew, in what Ratio the Velocity is retarded in one, and accelerated in the other.

EXPERIMENT I.

PREPARATION.

LET each of the Balls D and F be 2 Ounces in Weight, and make them fall at the ſame Time, one in an Arch of 3 Graduations, and the other in an Arch of 6, being both taken on the ſame ſide.

EFFECTS.

THESE two Balls will joyn in the Place where their Threads of Suſpenſion are perpendicular to the Horizon. A ſmall flattening is made in each, after which they continue to move together on the ſame Side, and aſcend an Arch of 4 ½ Graduations.

EXPLANATIONS.

THE Ball F having 6 Degrees of proper Velocity againſt 3, approaches to the Ball D with a relative Velocity of 3 Degrees, or the Exceſs of 6 above 3. We ſhall tell elſewhere why it comes to paſs, that when the Motion is made in Arches of the ſame Circle, tho' unequal ones, yet the two Balls will ſtrike exactly in that Place, which is the loweſt of their Falls.

As to the ſinkings of the Parts which touch in the Shock, they ought to be proportional to the relative Velocity, which is leſs than the abſolute or proper Velocity of the ſtriking Body in the preſent Caſe; wherein the Ball that is ſtruck moving the ſame way, partly avoids the Force of the Stroke.

LASTLY, the two Balls aſcend together in an Arch of 4 ½ Graduations. That is to ſay, that their common Velocity compared to that of the Ball F before the Shock, is found to be diminiſhed by a fourth Part. And this is what ought to be expected; for the ſtriking Body having 6 Degrees of Velocity, and meeting another Body of a Maſs equal to it's own, which has but 3 Degrees, ought to loſe ſo much of it as is neceſſary, that he may communicate to the other enough to enable it to move as faſt as itſelf. But the Equality of their Maſſes requires, that it ſhould give it 1 ½, which is the Half of 3, the Difference of the two Velocities before the Shock. Now 1 ½ taken from 6 and added to 3, makes 4 ½ in one, and as much in the other.

EXPERIMENT II.

PREPARATION.

THIS Experiment is performed as the firſt, with this Difference, that the Ball D weighs 4 Ounces, and the Ball F 2 Ounces; the Velocities remaining in the Ratio of 3 to 6.

EFFECTS.

AFTER the Colliſion the two Balls continue to move together. The flattenings are greater than in the foregoing Experiment; and the Arch they deſcribe is of 4 Graduations.

EXPLANATIONS.

WHAT we have ſaid to explain the firſt Experiment may be applied to this. We ſhall only make Uſe of the ſame Reaſoning, obſerving the Proportions. The Exceſs of the Velocity in the Ball F before the Shock was 3, which muſt be diminiſhed by two Thirds, by the Reſiſtance of the Ball D, which has a double Maſs. So that after the Shock there ſhould be found 4 Degrees of Velocity, becauſe of 6 which was in the ſtriking Body; there are only 2 loſt by the Action, which makes the Velocity the ſame in both the Balls.

THE flattenings are greater than in the firſt Experiment, becauſe the Reſiſtance of the Body ſtruck was ſtronger. This we ſhall eaſily admit, when we conſider, that the Ball D being 4 Ounces, conſumed a third Part of the Velocity of the ſtriking Body; whereas being only two Ounces in the foregoing Caſe, it only conſumed a Quarter of it.

EXPERIMENT III.

PREPARATION.

LET the Ball D have 2 Ounces of Maſs, the Ball F 4 Ounces, and let the Velocities be in the Ratio of 6 to 3.

EFFECTS.

AFTER the Impulſe the Ball D is carryed away by the Ball F, ſo that they deſcribe together an Arch of 5 Graduations. And the Flattenings are leſs than in the two preceding Experiments.

EXPLANATIONS.

THE Ball F dividing it's Exceſs of Velocity, which is 3, with a Maſs which is leſs by half than itſelf, retains two thirds of it. Therefore the two Maſſes joined together after the Shock ought to have 6 Degrees of Velocity, except 1 which is taken away by the Reſiſtance of the Body ſtruck, before it aſſumes the ſame Velocity as the ſtriking Body.

THE flattenings are not ſo great as in the preceding Caſes, becauſe the Reſiſtance was not ſo ſtrong on the Part of the Body ſtruck. For 2 Ounces of Bulk reſiſt 4 Ounces, leſs than 4 reſiſts 2, or 2 reſiſts 2: The Velocities being ſtill in the ſame Ratio.

APPLICATIONS.

APPLICATIONS.

IT is eaſy to ſee by the Experiments of the ſecond Propoſition, that after the Shock of two Bodies, of which one moves faſter than the other in the ſame Direction, the proper Velocities, in order to become equal, in one Change from more to leſs, and in the other from leſs to more. Since that of the Body D has always been encreaſed, and, on the contrary, that of the Body F has always undergone ſome Diminution. 'Tis thus that a Boat which complies with the Impulſe of the Oars, receives an Increaſe of Velocity, and retards that of a Volume of agitated Air, in the Direction of which it moves. It does not go ſo ſwift as the Wind, but it's Motion is always quicker than if it had moved only by the Strength of the Rowers.

THE ſwifteſt Flight, the hardeſt running, does not hinder but that the Bullet of the Sportſman ſhall overtake the Game that flies before him. But at equal Diſtances the Blow is not ſo ſure, as if the Animal ſat ſtill, or came the contrary way. And it is well known that a Hare, a Buck, *&c.* ſhot in the Flank, is more eaſily knocked down, than when he flies before the Stroke. One of the Reaſons that may be given for it is, that then the relative Velocity of the Bullet is greater, becauſe the Animal moves in a Direction which withdraws it but little or not at all from the Sportſman, which is then as it were fixt. We have ſeen by the Experiments of the firſt Propoſition, that in ſuch a Caſe the Shock is greater.

PROPOSITION III.

IF the two Bodies which are to impinge move directly contrary ways, the Motion will be deſtroyed in both, or at leaſt in one of them. If any remains after the Shock, the two Bodies will go the ſame way, and the Quantity of their common Motion will be equal to the Exceſs of one above the other before the Shock.

THAT is to ſay, that in the Caſe wherein the two Motions are equal before the Shock, the two Bodies will be reduced to a State of Reſt. And if one of them had more than the other before the Percuſſion, there would remain afterwards only the exceeding Quantity, which would be the common Motion of the two Bodies. The two following Experiments will prove this.

EXPERIMENT I.

PREPARATION.

THE Ball D weighing 2 Ounces, and the Ball F as much, one is raiſed in an Arch of 6 Graduations on one Side, and the other in an equal Arch on the contrary Side; and both are let fall at the ſame Time.

EFFECTS.

THESE two Bodies will meet each other in the loweſt Place of their Fall, where they will remain at Reſt. And their flattenings are greater than in the Caſe, wherein the Ball F falls in an equal Arch againſt the Ball D at Reſt, or if it flies before it.

EXPLANATIONS.

IN this Experiment, the Quantity of Motion is equal on both Sides. For in each Ball before the Shock, we reckon 6 Degrees of Velocity drawn into 2 Ounces of Maſs. Two Bodies that meet, moving contrary ways, give mutual Reſiſtance to each other. Here on each Side the Force or Power is kept in Equilibrio by an equal Reſiſtance, and this Equilibrium produces a State of Reſt in both the Bodies.

THE flattenings are greater than they were in the Experiments of the two firſt Propoſitions, in which we have always given 6 Degrees of Velocity to the ſtriking Body. But it muſt be conſidered, that the relative Velocity, on which the Force of the Shock depends, is double or more than double. For when the Ball D was at Reſt before the Shock, the relative Velocity of F was nothing elſe but it's proper Velocity,

city, that is 6, or leſs than 6, when the Ball D fled before it. Here the two Balls having 6 Degrees of proper Velocity, in going one towards another, the relative Velocity is 12; that is to ſay, the Space which ſeparates them before the Shock is deſcribed in as little Time again.

EXPERIMENT II.

PREPARATION.

THE two Balls D and F are made to move one towards another, as in the foregoing Experiment; and their Quantities of Motion are put in the Ratio of 12 to 24, by doubling the Maſs or the Velocity of F.

EFFECTS.

AFTER the Shock the two Balls continue to move in the Direction of F, with 2 Degrees of Velocity, if the Motion was doubled by the Maſs; or with 3, if it was doubled by the Velocity.

EXPLANATIONS.

IF the 24 Degrees of Motion of the Ball F proceed from 4 Ounces of Maſs, and 6 Degrees of Velocity; when it meets the Ball D coming againſt it with

12 Degrees of Motion, produced by 2 Ounces into 6 Degrees of Velocity ; it oppoſes it's double Maſs and Half of it's Velocity to ſtop it, and that is ſufficient. For 3 of Velocity into 4 of Maſs, equals the whole Motion of the Ball D, which is 12. There remains then to the Ball F 3 Degrees of Velocity, with which it continues to act upon D, which we muſt conſider as at Reſt immediately after the Contact. But it cannot move a Body at Reſt, but by communicating ſome Velocity to it at the Expenſe of it's own ; and we have ſeen, that this Communication is made in the Ratio of the Maſſes. As the Ball D has but 2 Ounces of Maſs againſt 4, the Ball F will loſe only a third Part of the Velocity that remains to it. So that the common Velocity after the Shock, is 2 for two Maſſes, which taken together are equal to 6 Ounces.

We ſee then, firſt that the Motion which remains after the Shock, is equal to the Difference of the two Quantities before the Shock ; for 12 is the Exceſs of 24 above 12. Secondly, that this Difference divided by the Sum of the Maſſes, gives the common Velocity after the Shock. For 12 divided by 6, the Sum of 2 and 4 Ounces, gives 2 Degrees of Velocity, as the Experiment has repreſented it to be.

We ſhould find the ſame thing if we had doubled the Motion of the Ball F, by doubling it's proper Velocity. For then, in order to ſtop the Ball D, which we ſuppoſe to have 12 Degrees of Motion, and equal in Maſs, it would loſe 6 Degrees of Velocity. And to carry it with it, it muſt ſtill communicate to it 3 of thoſe 6 which remain to it. After the Shock there will then remain 3 Degrees of Velocity in common to 4 Ounces of Maſs, the Sum of the two Balls. And conſequently the Quantity of Motion would be always 12, the Difference of 24 and 12.

APPLICATIONS.

THESE laſt Experiments ſhew in general, why we muſt uſe more Force to repel a Body that way which is contrary to it's Motion, than merely to ſtop it. For we muſt not only make Uſe of a Force equivalent to it's own, to overcome it's firſt Motion, but we muſt ſtill add all that is neceſſary, to make it acquire a new Motion. 'Tis for this Reaſon that we muſt make a ſtronger Effort, to make a Ball go backwards which is rolling upon a Plain, than to ſtop it by oppoſing it's Progreſs. But we have ſeen at the ſame Time, that the Effort of a moving Body which is going againſt another, may be increaſed both by it's Velocity and by it's Maſs. We therefore cannot be ſurprized to ſee, that Players at Tennis ſometimes find their Racket too light; becauſe, ſuppoſing the Stroke to be ſtruck with the ſame Velocity, it's Effect will not be ſo great, if the Maſs with which it is given is too light and feeble.

COROLLARY.

IT follows from the two firſt Propoſitions, and from the Experiments made Uſe of to prove them, firſt, that when the Motions are not mutually oppoſite, the two Maſſes united after a Shock, exhibit the ſame Quantity of Motion which ſubſiſted in one of them, or in both before the Contact. Let us take the firſt Experiment of the firſt Propoſition for an Example.

BEFORE the Shock the whole Motion reſided in the Ball F, the Quantity of which was 12, the Product of 6 Degrees of Velocity by 2 Ounces of Maſs. After the Shock the Quantity of Motion in the two Balls united was ſtill 12, the Product of 4 Ounces of Maſs by 3 Degrees of Velocity in common. This Calculation may eaſily be applied to the other Experiments, and we ſhall always find the ſame Concluſion.

FROM this firſt Conſequence there ariſes another, which is, that if we know the common Velocity after the Shock, we may know what is the Sum of the Maſſes; and *vice verſâ*, the Sum of the Maſſes will ſhew the common Velocity. For an Example, we will take the firſt Experiment of the ſecond Propoſition.

THE Sum of the Motions before the Shock was 18, that is 12 the Product of 2 Ounces by 6 Degrees of Velocity, and 6 the Product of 2 Ounces by 3 Degrees of Velocity. According to the firſt Conſequence, the two Maſſes after the Shock ought to exhibit together a Quantity of Motion equal to 18. We know the whole Maſs is 4 Ounces. Divide 18 the Quantity of Motion, by 4 the Sum of the Maſſes, and the Quotient $4\frac{1}{2}$ is the common Velocity.

AGAIN, we know the common Velocity is $4\frac{1}{2}$, and we ſhall know the Sum of the Maſſes is 4, by dividing 18 by $4\frac{1}{2}$.

LASTLY, we ſee by the third Propoſition, firſt, that when the Bodies ſtrike one another by meeting directly, a Part of the Motion is loſt. Secondly, that as in the other Caſes, we may judge by the common Velocity after the Shock, and by the Ratio of the Maſſes, what were the proper Velocities before the Shock. Or elſe what is the Ratio of the Maſſes, by comparing the common Velocity with the proper Velocities.

ARTICLE II.

Of the PERCUSSION *of Elaſtick* BODIES.

IN all the Experiments which have ſerved as Proofs of the Propoſitions concerning the Shock of non-elaſtick Bodies, we have always obſerved two principal Effects, that is, a Communication of Motion from the ſtriking Body to the Body ſtruck, and a Change of Figure or a flattening of each at the Place of Contact. Theſe two Effects have one common Cauſe, which is the Percuſſion. 'Tis by this Action that the Velocity is tranſmitted, and is diſtributed uniformly between the two Maſſes. But during the Time this Diſtribution is making between the two Bodies, their Figures are changed, and the flattening that proceeds from thence, depends particularly on the longer or ſhorter Reſiſtance of the Body that is ſtruck. 'Tis for this Reaſon, that tho' the relative Velocity ſhould be always the ſame, the Quantity of the flattenings would always vary, according to the Ratio of the Maſſes which ſtrike one another; as may be obſerved from the foregoing Experiments.

In the Shock of elaſtick Bodies, Nature is uniform, and always follows the Laws ſhe has preſcribed herſelf, which we have ſeen in the Percuſſion of Bodies that are non-elaſtick. But as the Parts ſunk in by the Stroke, reſtore themſelves with the ſame Velocity with which they were diſplaced; this laſt Effect, which is blended with that of the Motion communicated by the Shock, introduces a great Change in the Reſults.

We muſt therefore carefully diſtinguiſh two Sorts of Motion, in the Percuſſion of elaſtick Bodies. One, which is independent of Elaſticity, and which we will call *primitive Motion*. The other ariſes from the Reaction of the Bodies, which are flattened or compreſſed by the Shock, which we will call *Motion of Elaſticity*, *reflected Motion*, or ſimply *Reaction*.

PROPOSITION I.

When an elaſtick Body ſtrikes another elaſtick Body which is at Reſt, or which moves the ſame way with it, this, after the Shock, moves in the Direction of the ſtriking Body, and with a Velocity compounded of that which was given it immediately, or by Communication; and of that which it acquires by it's Reaction after the Shock. And the ſtriking Body, the Spring of which acts the contrary way, loſes either wholly or in part what it had kept of it's firſt Velocity. And if it's reflected Motion exceeds the Remainder of it's firſt Velocity, it goes back according to the Quantity of this Exceſs.

THESE general Expreſſions will be better underſtood, if we apply them to particular Caſes. Let us ſuppoſe then the Maſſes to be equal. In conſequence of this firſt Suppoſition, I ſay, that, after the Shock, that Body which was at Reſt will receive, as well by Communication as by it's Reaction, a Quantity of Motion, equal to that which the other Body had before the Percuſſion; and this will be reduced to Reſt by it's Spring, which will deſtroy the Remainder of it's primitive Velocity.

IF we ſuppoſe the Maſſes to be unequal, and that the Body ſtruck is the leaſt; after the Shock both will go in the Direction of the ſtriking Body, but this will have leſs Velocity than the other.

LASTLY, if the Body ſtruck has more Maſs than the other, it will go alone in the Direction of the ſtriking Body, and this will return backwards.

LET us make theſe three Suppoſitions real, by ſo many Experiments, which will ſerve as Proofs of our firſt Propoſition, and of the Conſequences which we ſhall draw from thence. We ſhall make uſe of very round Balls of Ivory, which we ſhall ſuſpend by Threads, as we did thoſe of ſoft Earth, and by help of the ſame Machine.

EXPERIMENT I.

PREPARATION.

THE Ball D at Reſt weighs 2 Ounces. The Ball F is equal to it, and deſcends along an Arch of 6 Graduations.

EFFECTS.

AFTER the Shock, the Ball F remains at Reſt at the Place of Contact, and the Ball D deſcribes an Arch of 6 Graduations on the oppoſite Side. This ſhews, that the Body ſtruck received a Velocity equal to that of the ſtriking Body.

EXPLANATIONS.

THE Ball F meeting the Ball D at Reſt, will communicate to it half it's Velocity, becauſe of the Equality of their Maſſes; and for the ſame Reaſon it keeps 3, to continue it's Motion in the ſame Direction. Such would be the whole Effect of this Percuſſion, if the Balls had no Elaſticity, as we have ſeen by the firſt Experiment of the firſt Article. But becauſe of the Elaſticity, the Ball D being ſqueezed to it's flattening, reſtores itſelf, being ſupported againſt the Ball F; which is the Cauſe that this Reaction carries it forward, with the ſame Velocity it had been compreſſed. But this Velocity, is half that which made the two Balls meet, that is to ſay 3 Degrees. So that after the Shock, the Ball D will move with 6 Degrees of Velocity, that is 3 which it has received by Communication, and 3 which proceed from it's Reaction.

THE Ball F has kept 3 Degrees of it's primitive Velocity; but it's Reaction, which is equal, is made the contrary way, and makes it reſt.

EXPERIMENT II.

PREPARATION.

THE Ball D being 2 Ounces, and the Ball F 4 Ounces, to this are given 6 Degrees of Velocity, the other being at Reſt.

EFFECTS.

AFTER the Shock, the Ball D deſcribes 8 Graduations, in the Direction of the Ball F, and this continues to move on the ſame ſide, and deſcribes 2 Graduations.

EXPLANATIONS.

WE muſt firſt conſider the Motion communicated in the Ratio of the Maſſes, independently of the Elaſticity, and afterwards ſee what the Reaction adds to this firſt Effect, or what it takes from it.

If the Balls were not elaſtick, F of 4 Ounces meeting D of 2 Ounces at Reſt, would loſe only 2 Degrees of Velocity of the 6 which it has, and the two Maſſes would paſs on the ſame way with a common Motion, the Velocity of which would be 4, as we have ſeen above, *Prop.* I. *Exper.* II. But after the Shock, there is a reciprocal Reaction between the two Balls, becauſe of their Elaſticity; and this Reaction is equal to 4 Degrees of Velocity communicated, which have cauſed the Compreſſion. We muſt therefore conſider this Reaction as a Force, which exerts itſelf between the two Balls, to repel them from each other. It concurs with the Motion communicated to the Ball D, and increaſes it by half. On the contrary it tends to deſtroy that which remains to the Ball F. But we muſt take notice, that this laſt Maſs is of 4 Ounces, double to the other, and that the Reaction which can make 2 Ounces advance 4 Spaces, to a Weight that is double, can only make it go back 2 Spaces. Thus the Ball F, notwithſtanding it's Reaction, advances ſtill 2 Graduations after the Shock, by virtue of it's primitive Motion.

EXPERIMENT III.

Preparation.

The Ball F of 2 Ounces, with 6 Degrees of Velocity, ſtrikes the Ball D at Reſt, which weighs 4 Ounces.

EFFECTS.

AFTER the Shock the Ball D deſcribes 4 Graduations, in the Direction of the Ball F, and this returns back the Space of 2 Graduations.

EXPLANATIONS.

THE Reſiſtance of the Ball D, againſt the Ball F, has reduced the primitive Velocity from 6 to 2, by virtue of it's double Maſs. But the 2 Degrees of Velocity, which it has received by Communication, have been the Occaſion of a Reaction of the ſame Quantity, which cauſes it to deſcribe 4 Graduations forward. The ſame Reaction acting upon F, which weighs only 2 Ounces, ought to have produced a double Effect; that is to ſay, that in virtue of it's Elaſticity, it ſhould deſcribe 4 Graduations backwards; but it has kept 2 Degrees of it's firſt Velocity. This Effect therefore is reduced to one half, ſo that it deſcribes no more than 2.

APPLICATIONS.

WE may obſerve by the Reſult of the three Experiments, now produced as a Proof of our firſt Propoſition, that the Motion of Reaction, always doubles that which the Body ſtruck acquires by Communication. For when the Ball D, by virtue of the primitive Motion of F, ought only to have had 2, 3, or 4 Degrees of Velocity, we have ſeen that it had 4, 6, or 8.

We ſhould farther obſerve, that this ſame Reaction, which doubles the Motion of the Body ſtruck to go forward, endeavours with as much Force to repel the ſtriking Body backwards. But this laſt Effect diminiſhes as the Maſs increaſes. For Example, when, by Virtue of this Force, the Ball D of 2 Ounces, received 4 Degrees of Velocity forwards, the Ball F of 4 Ounces, received only 2 backwards.

THESE two Obſervations may make us comprehend the Reaſon of ſeveral Effects, which we have every Day before our Eyes, and which it would be difficult to explain without the help of theſe Principles.

ALL Artificers that work in their Chambers upon Anvils, or Heaps of Iron, as Planiſhers, Goldſmiths, Watchmakers, *&c.* never fail to deaden their Blows by a Roll of Matting, or ſomething of a like nature, upon which they place the Block that bears the Inſtrument. Without this Precaution, a great Part of the Force impreſſed by the Hammer, would be tranſmitted to the Floor, and would create ſhakings to the prejudice of the Building.

'TIS for like Reaſons, that they conſtruct the Ramparts of fortifyed Places of Brickwork. For if they build them of Free-ſtone, or other hard Materials, when Cannon-Balls come to ſtrike againſt theſe elaſtick Bodies, they would tranſmit their Motion to a greater Depth, and would cauſe more Damage.

THE Effects which reſult from the reciprocal Reaction of two elaſtick Bodies, which are ſqueezed by Percuſſion, would be the ſame if theſe two Bodies, abſtracting from their Elaſticity, had preſſed between them a third Matter capable of reſtoring itſelf. As if for Example, a Ring of Steel, *Fig.* 18. was ſtruck at the ſame time on each Side, by two Balls A and B, ſuſpended by Threads. This Ring compreſſed by the double Shock, as it reſtored itſelf would repel the two Bodies which had ſtruck it, at Diſtances proportional to their Maſſes. That is to ſay, equally far if they were equal, or that of the two the farther, which is not ſo heavy as the other.

WE are to expect the ſame thing from a Body, the Spring of which being bent before-hand, unbends itſelf between two moveable Bodies. As if the Steel Ring we ſpoke of was compreſſed by a diametrical Thread, and was permitted to unbend againſt the two Bodies A and B. They would be both impelled contrary ways, and at Diſtances which would be in a reciprocal Ratio of their Weights.

THESE Effects, which are Conſequences from our firſt Propoſition, will ſerve to explain the recoiling of Guns, Fuſees, and all Fire-arms. For we ought to look upon the Powder, which is fired between the Breech and the Ball, as a Spring which unbends both ways. It's Action in the two moving Bodies produces a Velocity, which is ſo much the greater in one of the two, as it's Maſs is relatively leſs than the other. So that as the Cannon, the Muſket, *&c.* (eſpecially conſidering the Obſtacles which retain them) are much more difficult to move, than the Ball or Bullet with which they are charged; we may eaſily conceive, why the latter Body receives from the inflamed Powder a vaſtly greater Velocity.

ANOTHER Reaſon farther contributes to augment the Velocity of the Ball. 'Tis a certain Length given to the Cannon, which affords time to the Powder to light, and to exert it's whole Action. If it is too ſhort, the Bullet will be gone out before the Exploſion is entirely finiſhed. This is one of the Reaſons why Piſtols never carry ſo far as Guns: And their Barrels are made longer, when they are intended to ſhoot at a good Diſtance. But even this Length has it's Limits. And when theſe are exceeded, inſtead of giving a greater Velocity to the Ball, on the contrary they loſe Part of it by a needleſs Friction, which would be prevented if the Barrel had a due Proportion.

As to the Recoil we may ſay in general, that ſuppoſing the Quantity and the Quality of the Powder to be alike, a Gun recoils ſo much the more, as the Charge of the Bullet makes the more Reſiſtance, either by it's Weight, or by the Wadding that keeps it in.

A Rocket flies up, becauſe it's lower Part, which is fired, performs the Office of a Spring, which acts one way againſt the Body of the Rocket, and the other way againſt a Volume of Air, which does not yield ſo faſt as it is impelled. And as this Spring is continually renewed by the ſucceſſive Inflammation of all the Parts of the Rocket, it accelerates it's Motion for two Reaſons. Firſt, becauſe it is contained in the Body itſelf, and therefore adds continually to it's Velocity. And, ſecondly, becauſe the Weight or Reſiſtance of this Body is diminiſhing every Inſtant, by the Diſſipation of the Parts as they burn away.

It may be aſked here, why upon a Billiard-Table, when a Ball is ſtruck againſt another at Reſt, the ſame thing does not happen as in the firſt Experiment, which ſeems to be juſt the ſame Caſe? When the Balls are equal, why does that which ſtrikes continue almoſt always to move? Ought it not to reſt without Motion after the Shock, as it happens to the Ball F, when it meets with D at Reſt?

Though theſe two Caſes ſeem to be like, yet they differ in this, that the Ball F in our firſt Experiment, has only one ſimple and direct Motion, whereas the Ball we would compare with it has two Motions. For not only it's Centre moves in a Right-Line, but at the ſame time it rolls upon the Plain, and all the Parts of it's Surface, deſcribe parallel Circles about it's Axis. When it ſtrikes a Ball at Reſt, the direct Motion of it's whole Maſs is ſtopt, for the Reaſons we have alledged. But that of it's Parts revolving about the common Axis ſubſiſts. So that at the Inſtant of the Shock, if the Plain were to vaniſh, and it was ſupported by it's Poles, we ſhould ſee it turn round without going forwards or backwards. But if this Motion of Rotation is made upon a Plain, it muſt neceſſarily carry the Ball forward; which is a thing eaſily conceived.

PROPOSITION II.

IF two elaſtick Bodies, whether equal or unequal in Maſs, ſtrike one another with proper Velocities, which are either equal or unequal; they will ſeparate after the Shock, and their relative Velocity will be the ſame as before the Shock.

IF theſe two Bodies were non-elaſtick, either they would reciprocally ſtop one another, or one of the two would carry away the other, as we have ſeen by the Experiments of the firſt Article. If they ſeparate, 'tis only in virtue of their Reaction. But we have alſo ſeen, that this Reaction is equal to the Compreſſion, which is as the relative Velocity before the Shock. Therefore that which reſults from it after the Shock muſt be equal to it; and this is what is confirmed by the Experiment.

EXPERIMENT I.

PREPARATION.

THE Ball D weighing 2 Ounces, and the Ball F the ſame; they are made to fall againſt one another along Arches of 6 Graduations each. This is the

Caſe wherein the Maſſes and the proper Velocities are equal.

EFFECTS.

AFTER the Shock the two Balls ſeparate, and each on it's own Side aſcends an Arch of 6 Graduations. Thus the proper Velocities are of 6 Degrees, and the relative Velocity of 12, as before the Shock.

EXPLANATIONS.

THE two Balls, by ſhocking one another with equal Forces, will loſe all their primitive Motion; but a Reaction equal to the Force with which they were compreſſed, or (which is the ſame thing) equal to their relative Velocity, has put them in a Capacity of re-aſcending the ſix Graduations which they had deſcribed by their Fall.

EXPERIMENT II.

PREPARATION.

LET there be given to the Ball D 4 Ounces of Maſs, and to the Ball F 2 Ounces, and let them fall one againſt another, the firſt along an Arch of 4 Graduations, and the ſecond along an Arch of 8. This is a Caſe wherein there is an Equality of Maſſes, and of proper Velocities, tho' the relative Velocity is ſtill 12.

EFFECTS.

AFTER the two Balls have ſtruck, they return to the Place from whence they parted before the Shock; which ſhews, that the relative Velocity is the ſame as before the Shock.

EXPLANATIONS.

IF the two Balls D and F of this Experiment had no Elaſticity, they would mutually ſtop each other, becauſe their Forces are equal. For 4 Ounces of Maſs, drawn into 4 Degrees of Velocity, give 16 for the Quantity of Motion; which is equal to 8 Degrees of Velocity drawn into 2 Ounces of Maſs. But theſe two Balls are elaſtick, and their Compreſſion is the Effect of a relative Velocity of 12 Degrees. The Reaction is therefore a like Velocity applyed on one Part to a Ball of 2 Ounces, and on the other to a Ball of 4 Ounces. But the Force which can tranſport 2 Ounces to 8 Graduations, can make a Maſs of 4 Ounces deſcribe only 4 Graduations, in the ſame Time. Therefore after the Shock, the two Balls ought to return to the Places they parted from, as the Experiment ſhews they do.

APPLICATIONS.

WHAT we have taught concerning the Percuſſion of two elaſtick Bodies, obtains alſo when there is a great Number of them contiguous to one another. And theſe Effects are executed with an Exactneſs to be admired. If for Example, we ſuſpend 7 or 8 Ivory Balls, ſo as to have their Centres all in the ſame Right Line, as is repreſented in *Fig*. 19. and if we make the firſt to fall in an Arch of a Circle againſt the ſecond; the eighth will ſeparate from the others with a Velocity equal to that, which the ſecond would have had after the Shock, if nothing had hindered it's Motion. And if we make two together to fall againſt the third, the two laſt will ſeparate from the others, which will all continue at Reſt.

IN like manner alſo, if we make the eighth to fall againſt the ſeventh on one Side, and the firſt againſt the ſecond on the other; theſe two ſtriking Balls will aſcend after the Shock, by the ſame Arches that they will deſcribe in deſcending, as if their Percuſſion had been immediate.

To explain theſe Effects it muſt be remembered, as we have obſerved above, that an elaſtick Ball, in the Inſtant of ſtriking, aſſumes an Oval Figure, by which not only the Part ſtruck is brought nearer the Centre, but alſo that which is diametrically oppoſite to it. Theſe two Parts reſtore themſelves im-

mediately,

mediately, and with Velocities equal to that with which their Compreſſion was made. We may conceive then, that the ſecond Ball being ſtruck by the firſt, immediately ſeparates itſelf a little from the third; and as well by Communication as by Reaction, having aſſumed a Velocity equal to that of the Body which ſtruck it, as we have explained in the firſt Experiment of the firſt Propoſition; it does to the following Ball what the firſt did to it. The ſame thing is done by the third and the fourth, and ſo on to the laſt, which being with-held by nothing, complies with the Impulſion it has received, and deſcribes an Arch which expreſſes a Velocity, equal to that of the firſt ſtriking Body.

These Examples of Motions communicated by contiguous elaſtick Bodies, will be of good Uſe to us hereafter, in confirming ſome Opinions (otherwiſe very probable) concerning certain Phænomena, in the Explication of which, the Philoſophers are not yet agreed. We ſhall content ourſelves at preſent to ſettle theſe Experimental Principles, which we ſhall afterwards make uſe of and appeal to, as the order of our ſeveral Subjects may require.

COROLLARY.

It may be obſerved from the Experiments we have produced, that when the elaſtick Bodies ſtrike one another in ſuch manner, that they continue to move in the ſame Direction, or that one of the two remains at Reſt after the Shock ; that then the Sum of the Motions is the ſame after as before the Percuſſion. For immediately before the Shock in the firſt Experiment, all the Motion reſided in the Ball F, the Quantity of which is 12, that is 6 Degrees of Velocity drawn into 2 Ounces of Maſs. And after the Shock a like Quantity is found again in the Ball D moving alone.

But if one of the two returns backwards, the Quantity of Motion is found to be greater after the Shock than before, as appears by the Reſult of the third Experiment. For before the Ball F meets the Ball D at Reſt, it's Quantity of Motion is 12, that is 6 Degrees of Velocity drawn into 2 Ounces of Matter. And after the Percuſſion the Sum of the Motions is 20; that is 16 in the Ball D, the Product of 4 Ounces by 4 Degrees of Velocity, and 4 in the Ball F, the Product of 2 Ounces by 4 Degrees of Velocity.

Not only the Sum of the Motions is greater after the Shock, but that of the Body ſtruck even exceeds that of the ſtriking Body before the Contact. For in the Ball F before the Shock the Motion was 12, and after the Percuſſion it is 16 in the Ball D, as we have now obſerved.

This Exceſs or this Difference of Motion in the Body ſtruck, is exactly equal to the Quantity of that which is retrograde after the Shock. This is what we ſhall ſoon perceive, if we conſider that the Quantity of Motion in the Ball F, which returns backward is 4, the Difference between 16 and 22.

Thus the Maſſes being known, if we know alſo the Velocity of that which goes backwards after the Shock, we may know the Quantity of Motion of the other, and what was the Sum of the primitive Motion.

We muſt not quit this Subject without taking notice, that we are not to eſtimate the Impulſe of Fluids, by the Rules we have ſettled concerning the Percuſſion of ſolid Bodies. For theſe having their Parts connected together, act with their whole Maſs; but it is not ſo with the Action of the others, becauſe of the relative Mobility of their Parts. None of them make any Effort but ſuch as are immediately and directly expoſed to the Shock. The reſt do not loſe their Velocity, and conſequently contribute nothing to the Effort. Wherefore Water and Wind, do not communicate at once their actual Velocity to a moving Body; 'tis only after a certain Time, that it receives the whole Motion that can be tranſmitted to it. We may eaſily be convinced of this, if we obſerve the Sails of a Wind-mill, or the Wheel of a Water-mill, when they are firſt put into Motion.

FINIS.

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Plate 1.

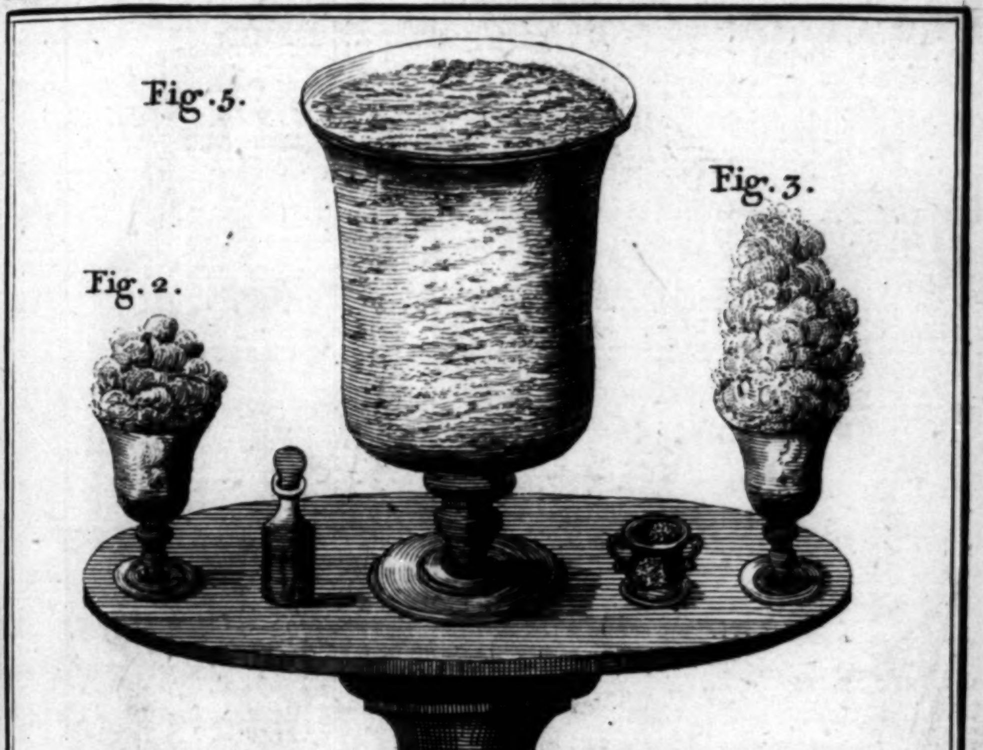
Fig. 5.
Fig. 3.
Fig. 2.
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Fig. 4.

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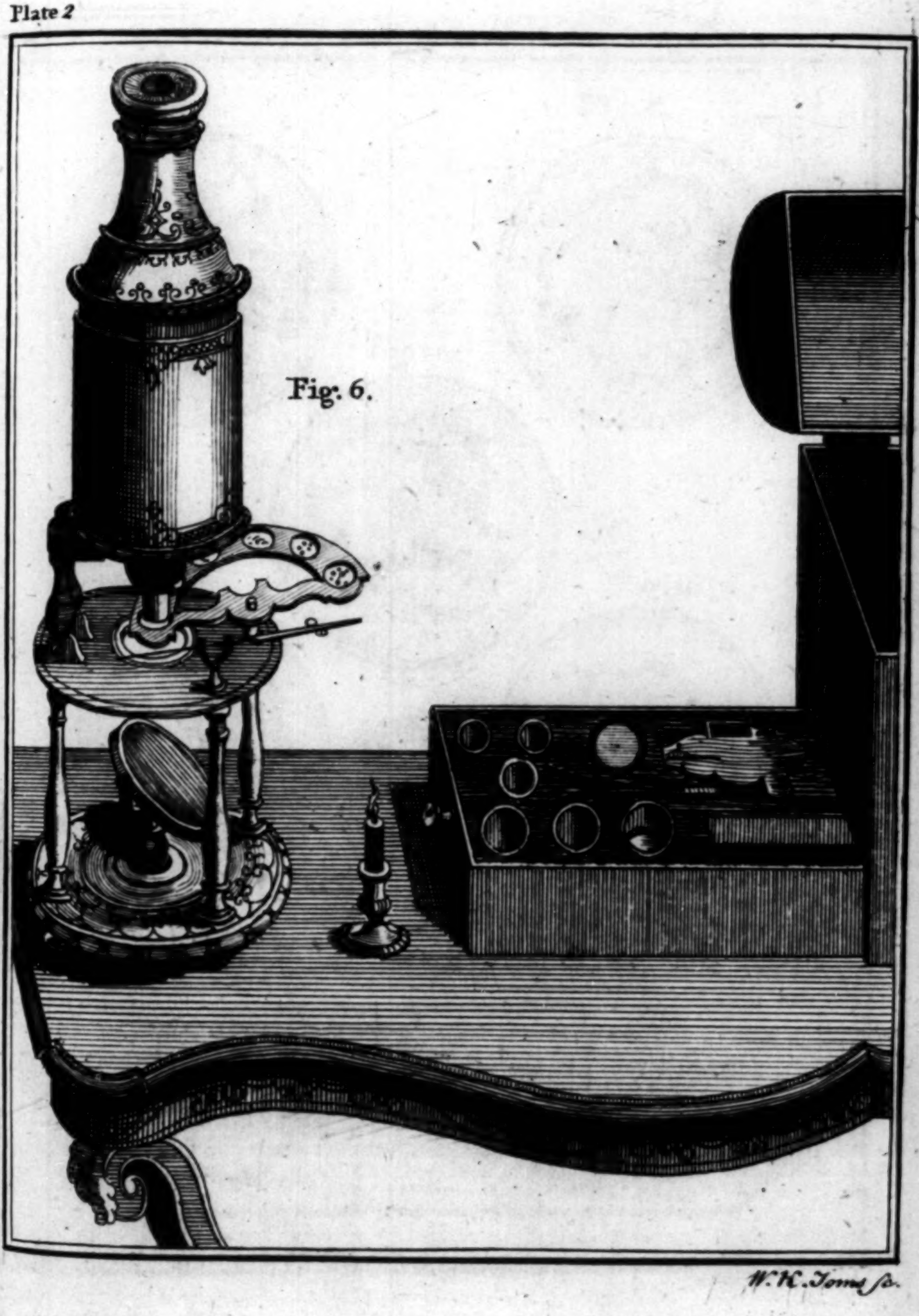
Plate 2



W. H. Toms sc.

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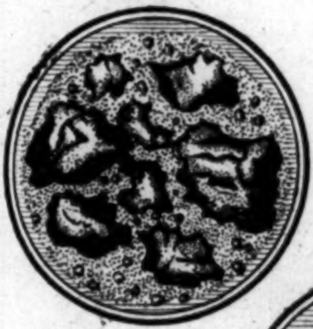
Plate 3.

Fig. 7.



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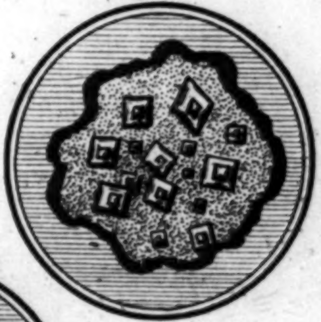

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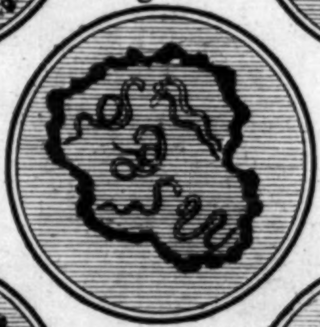

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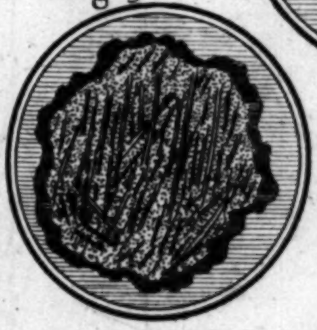

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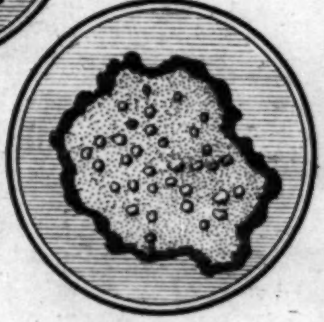

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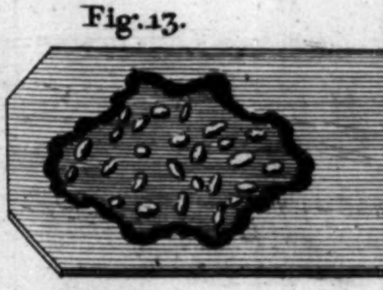

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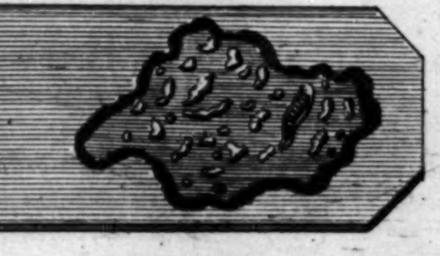

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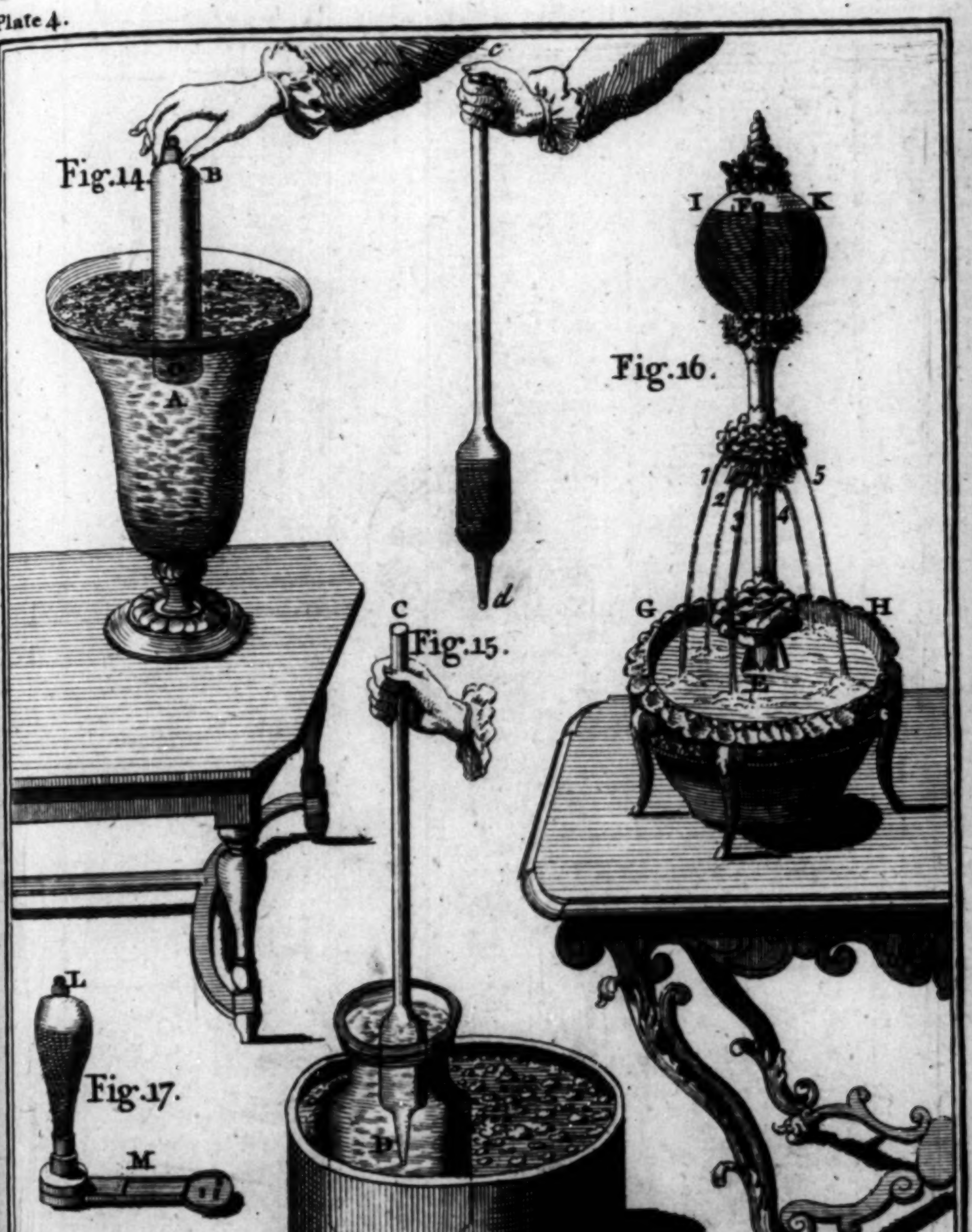
Plate 4.



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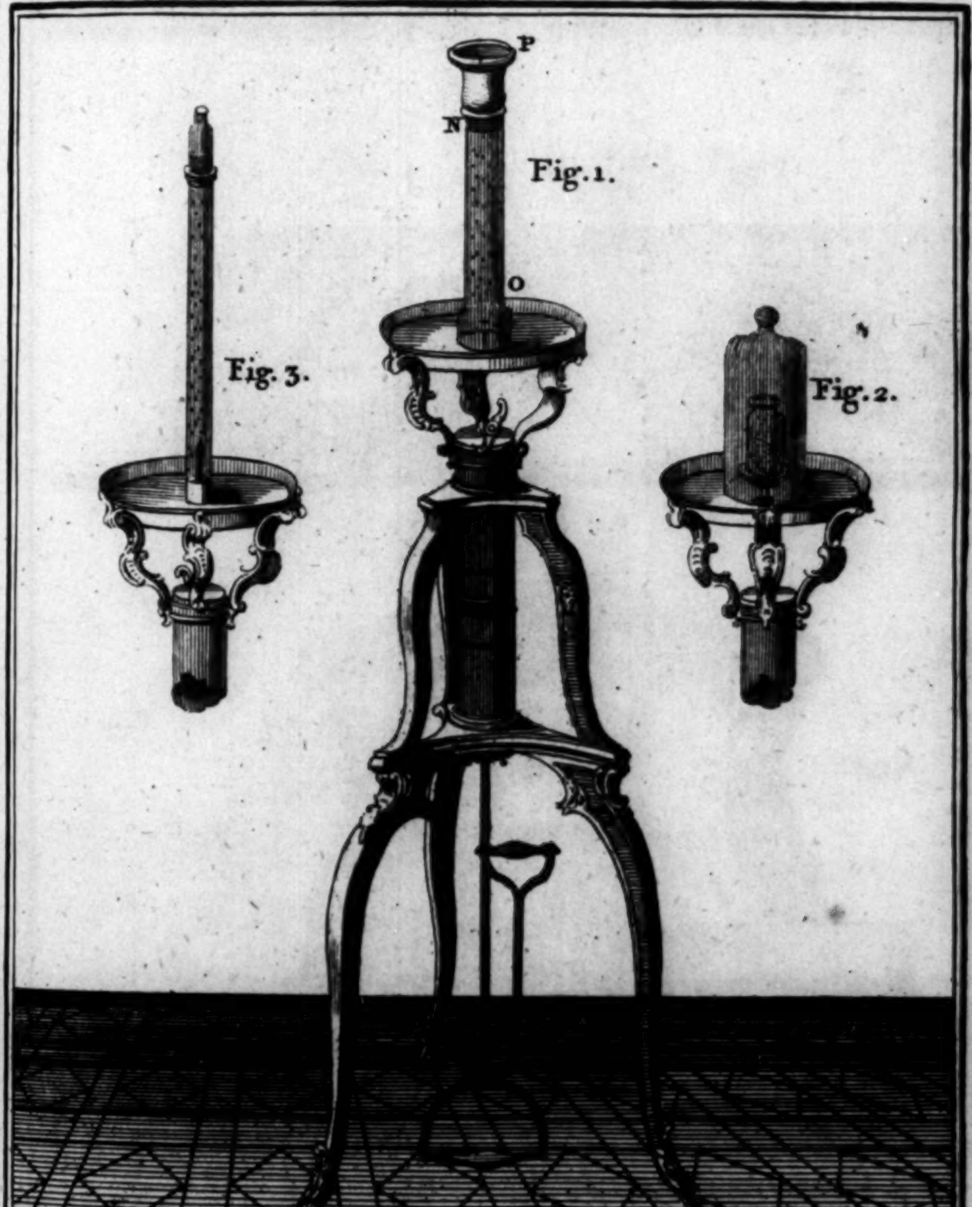
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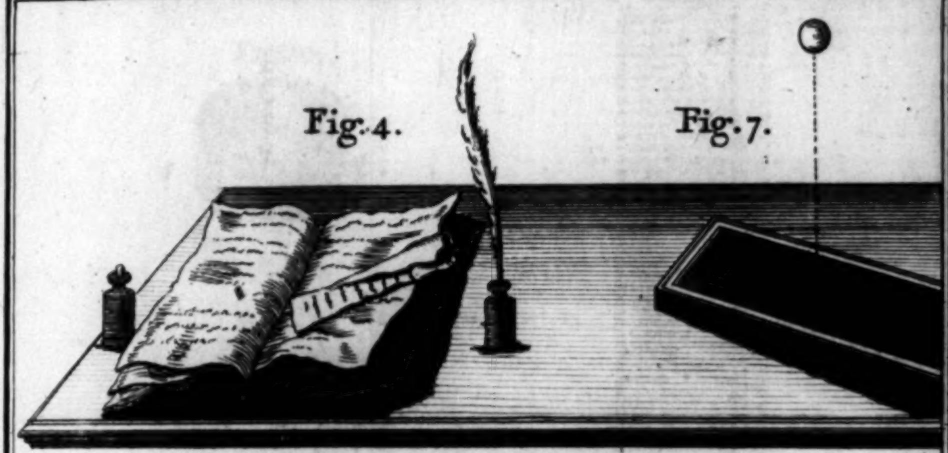
Plate 6.



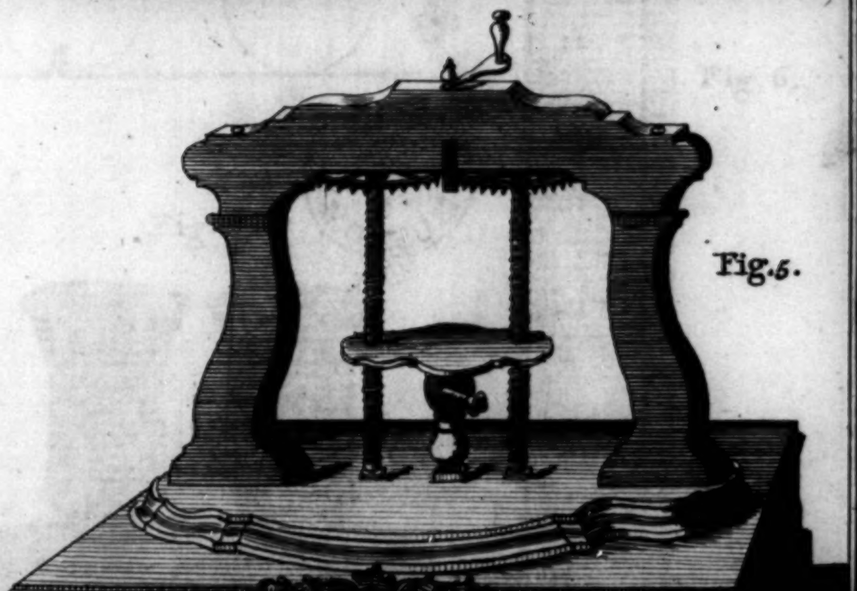


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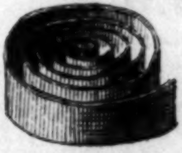
Plate 7.

Fig.10.



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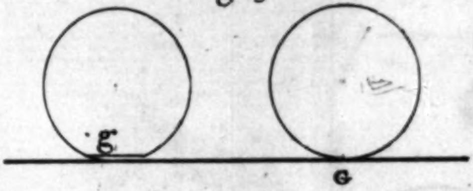

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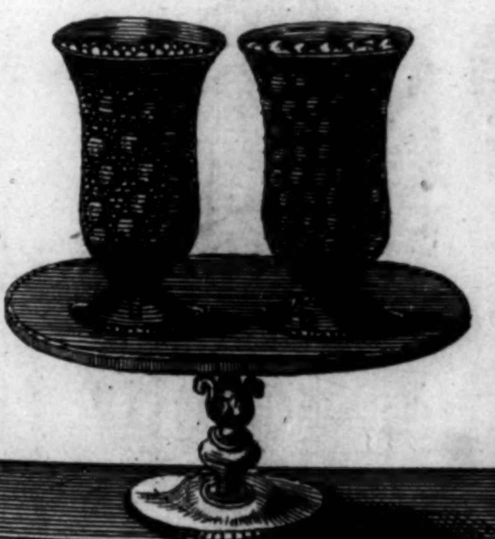

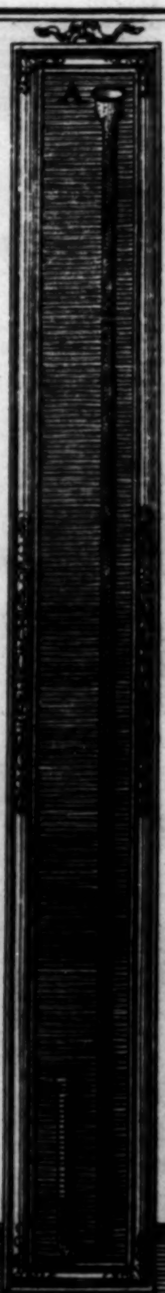

Fig. 6.

W.H. Toms Sculp.t

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Plate 8

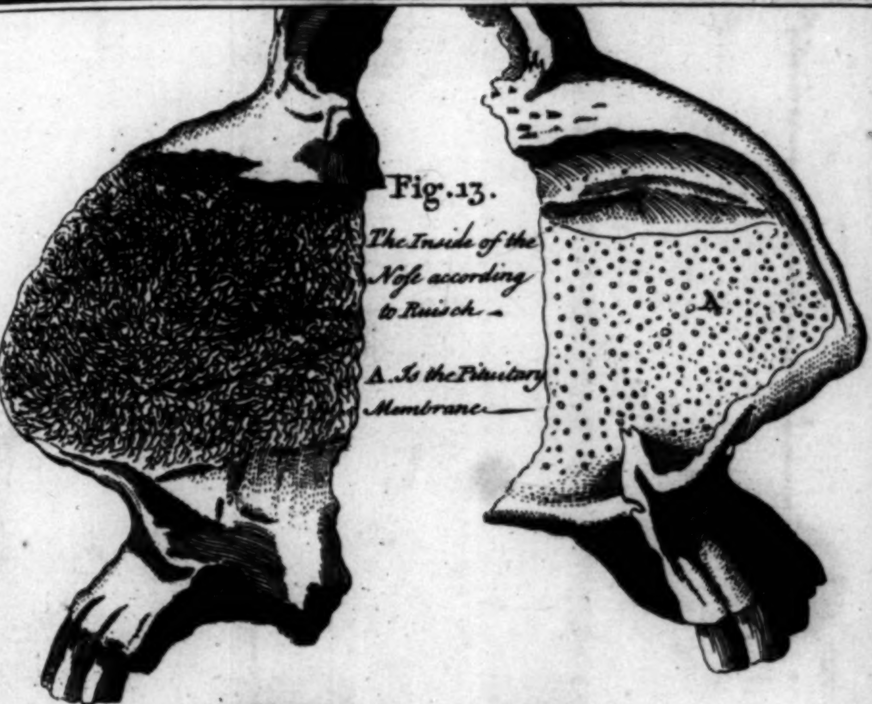

Fig. 13.

The Inside of the Noſe according to Ruisch –

A. Is the Pituitary Membrane –

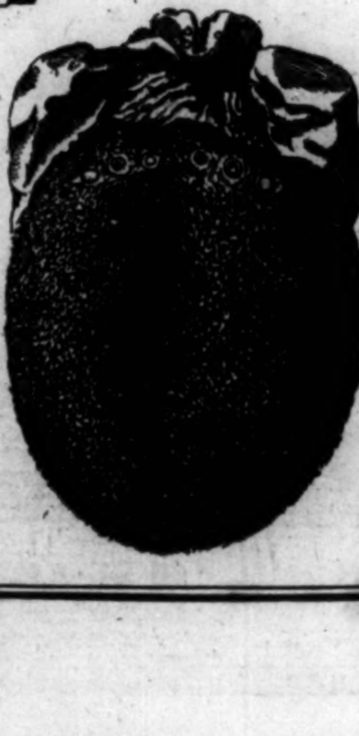

Fig. 12.

The humane Tongue Engraved after the manner of Quick's – *Theſaurus Anatomicus.*

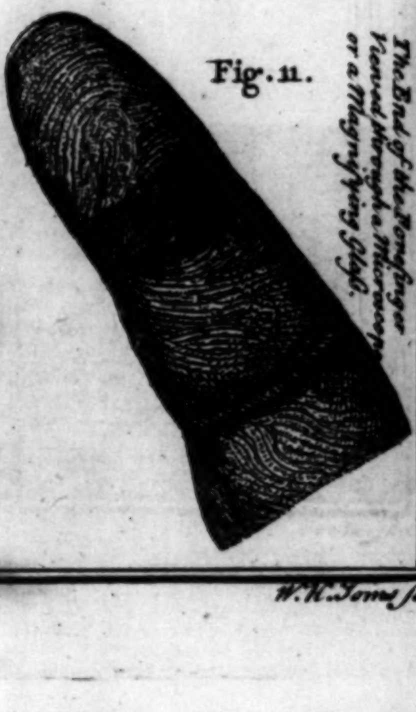

Fig. 11.

The End of the Forefinger Viewed through a Microscope or a Magnifying Glaſs.

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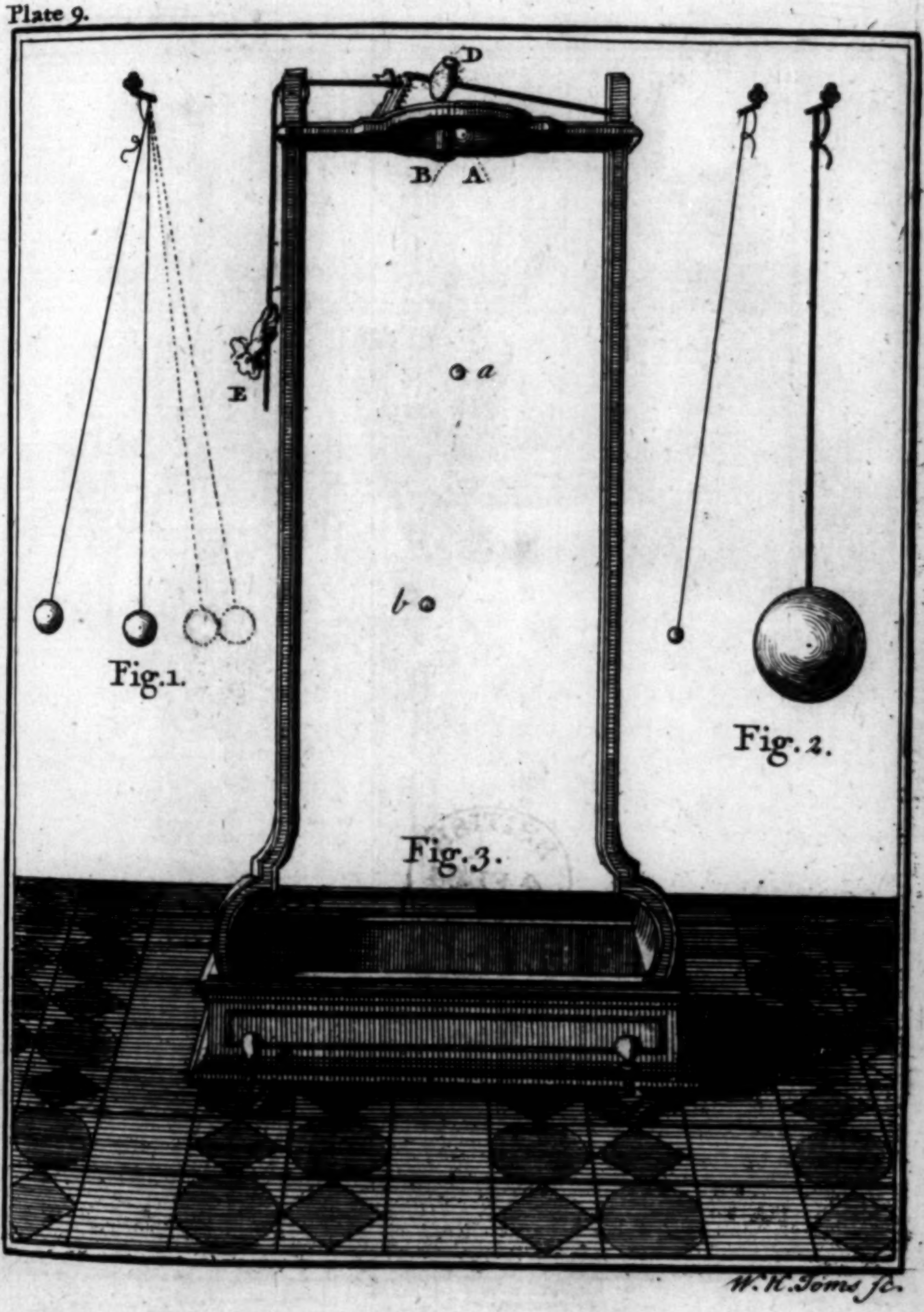
Plate 9.



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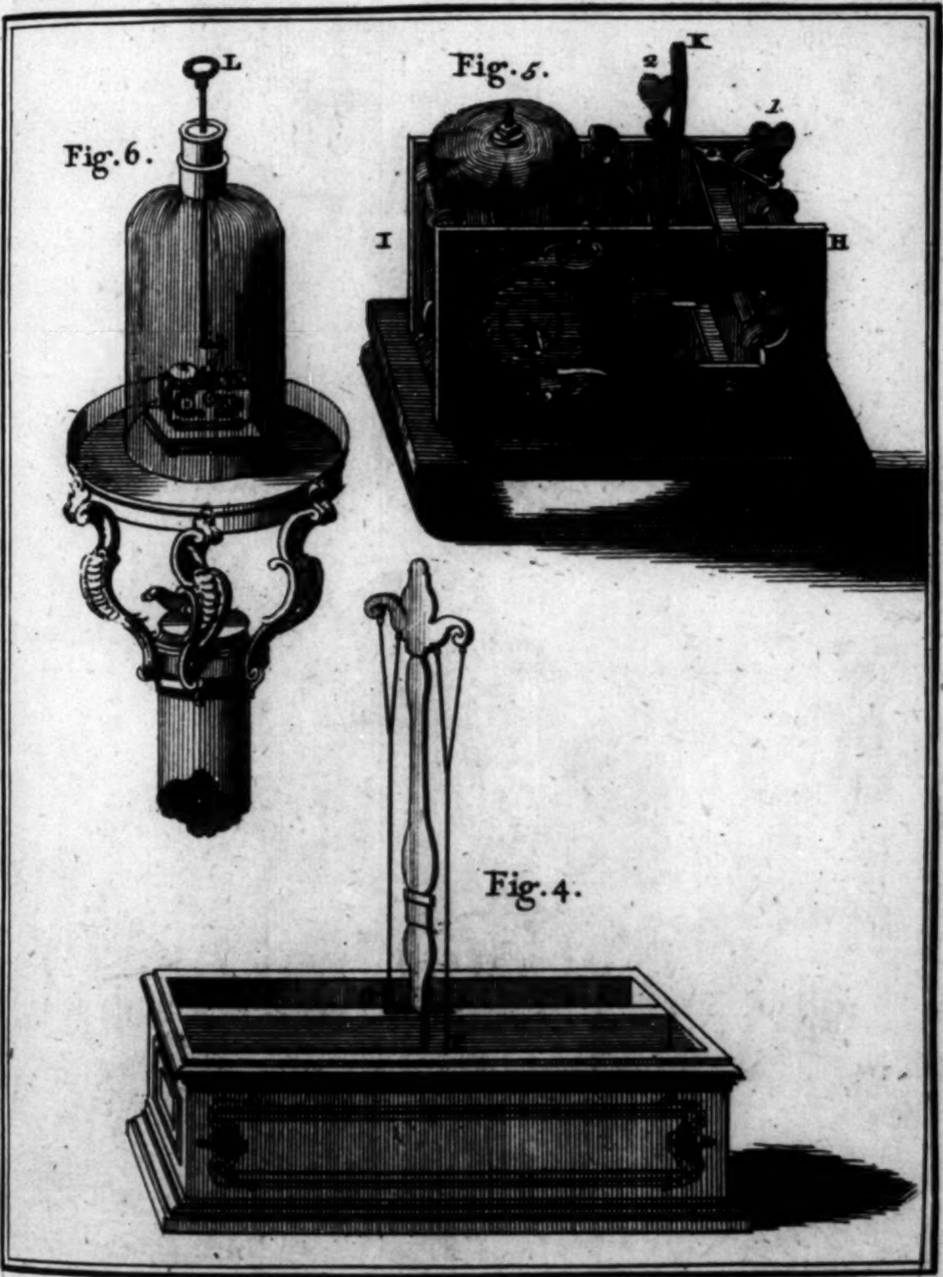

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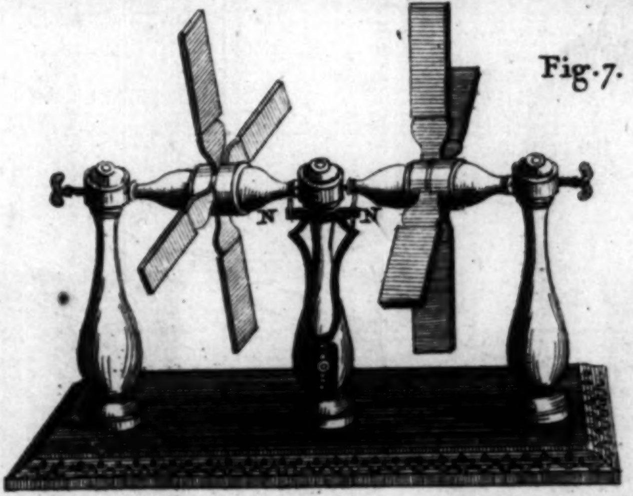
Plate 11.

Fig. 7.



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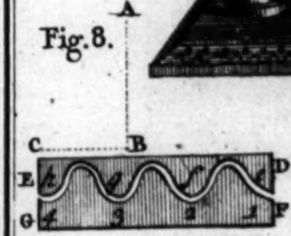

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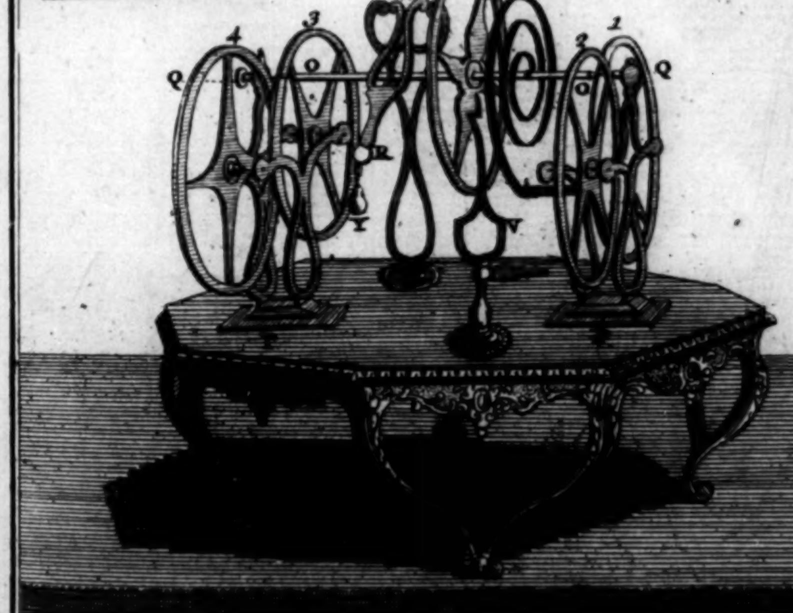

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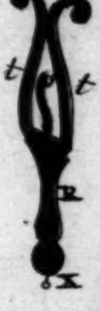

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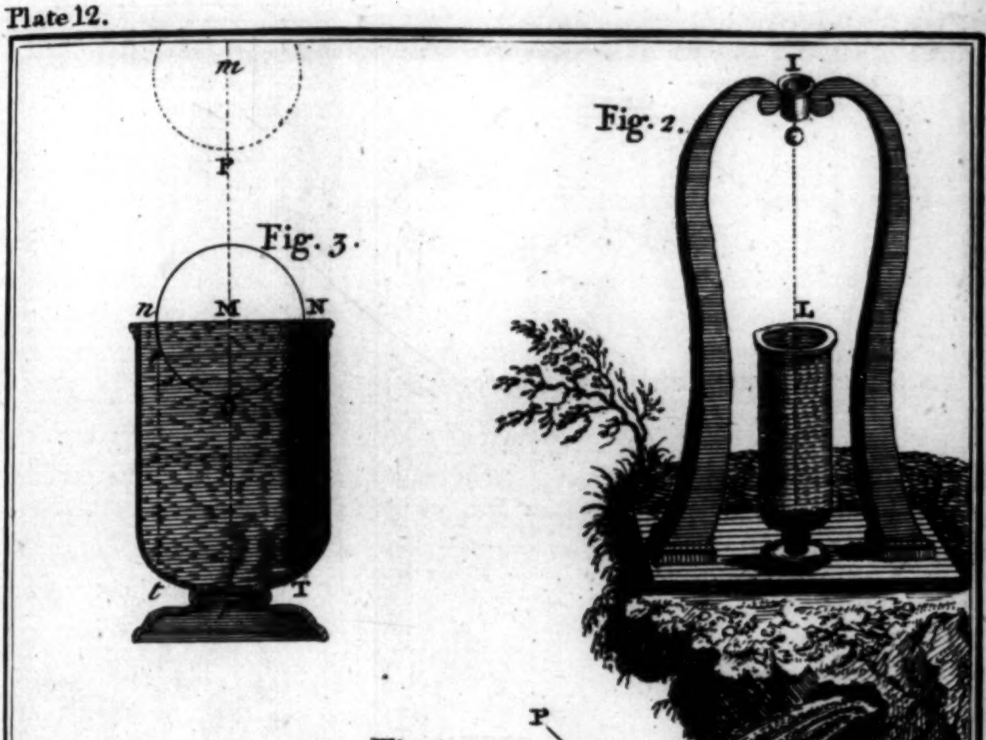

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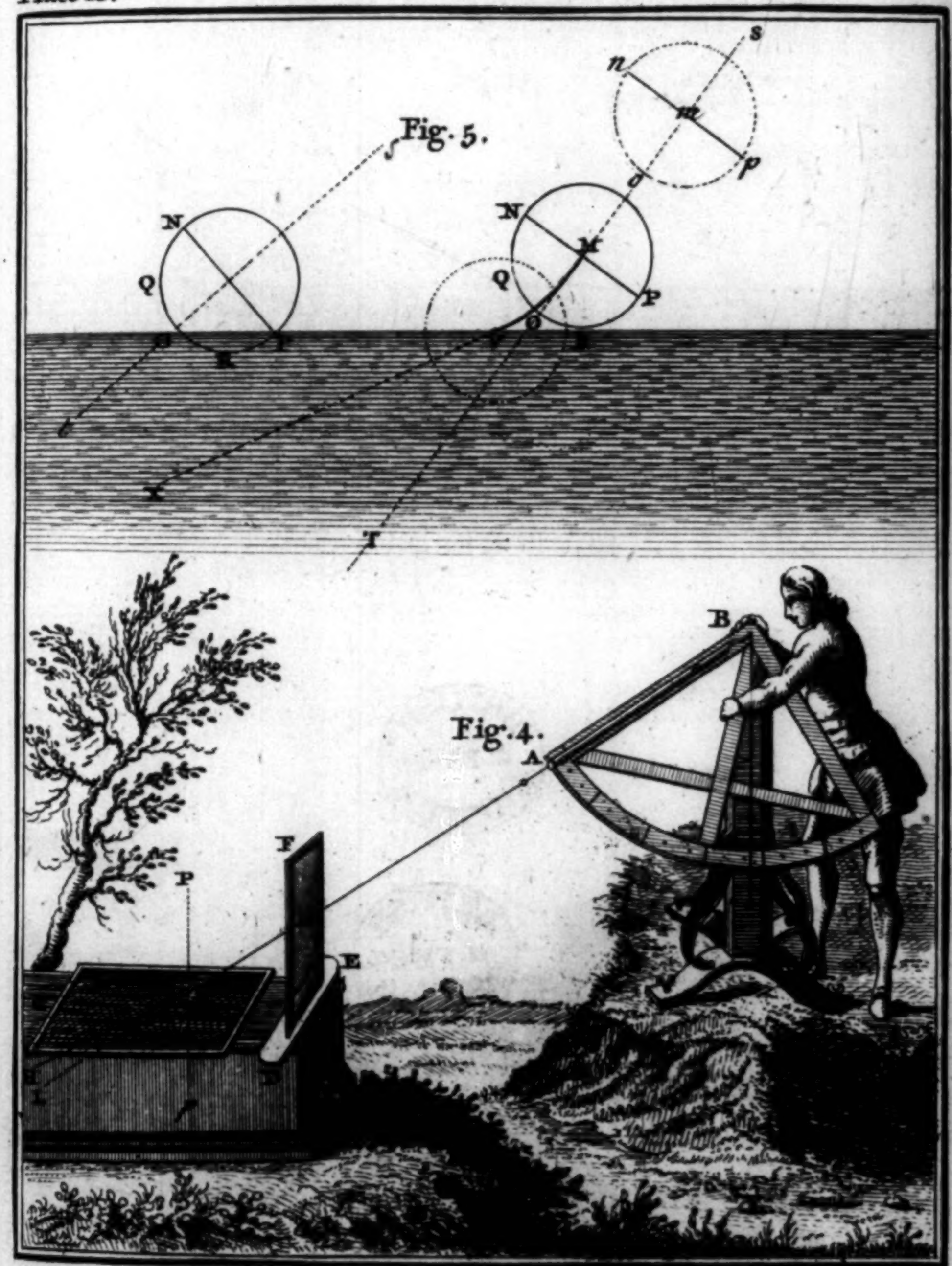

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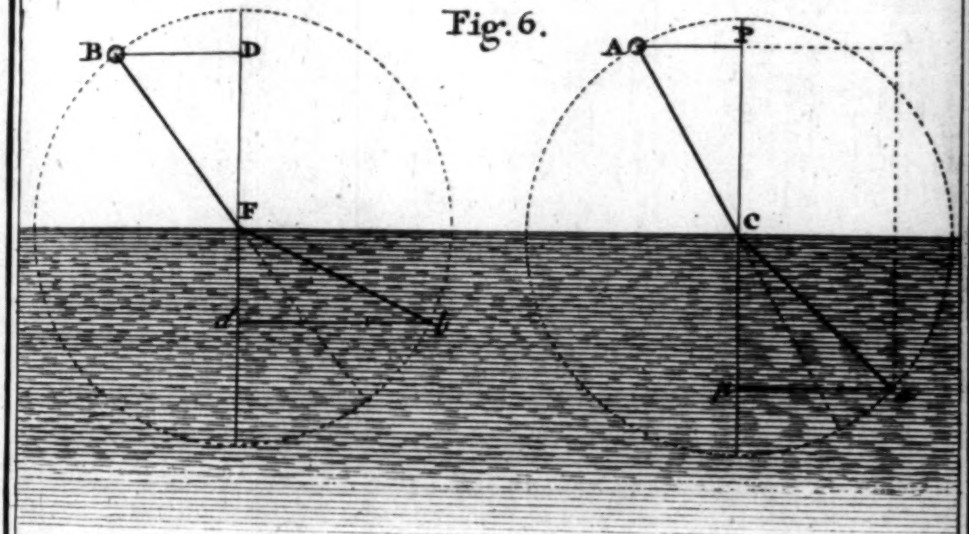
Plate 14.

Fig. 6.



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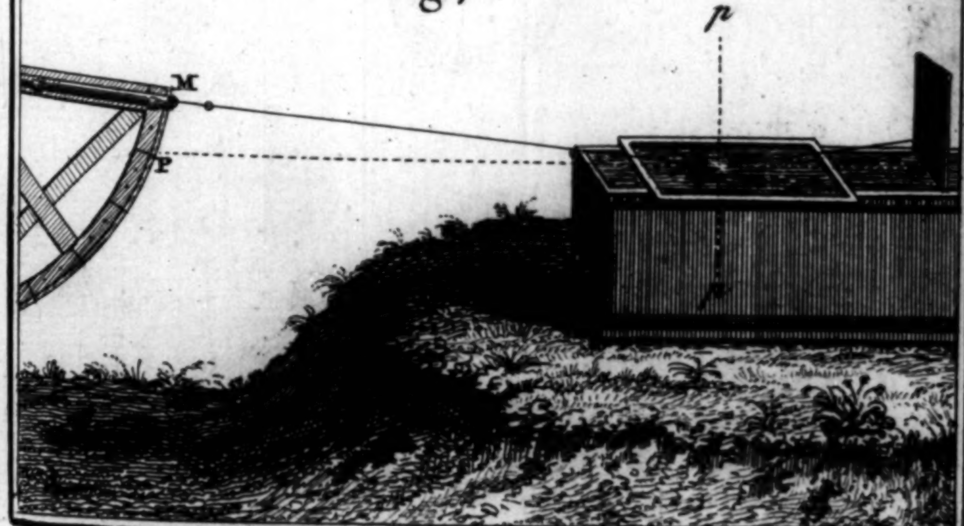

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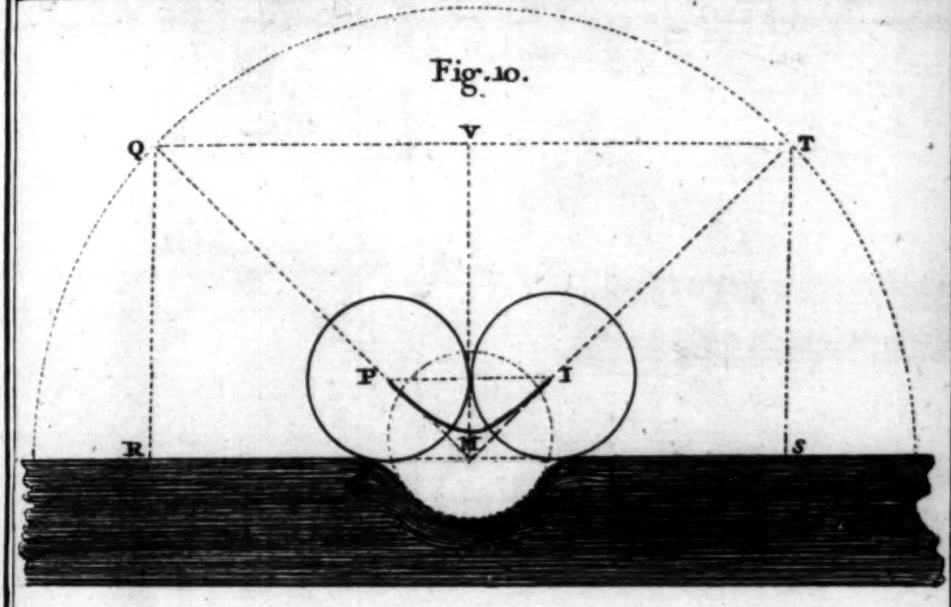
Plate 15.

Fig. 10.



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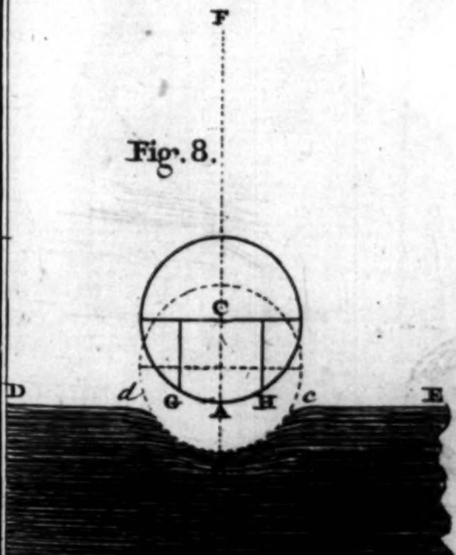

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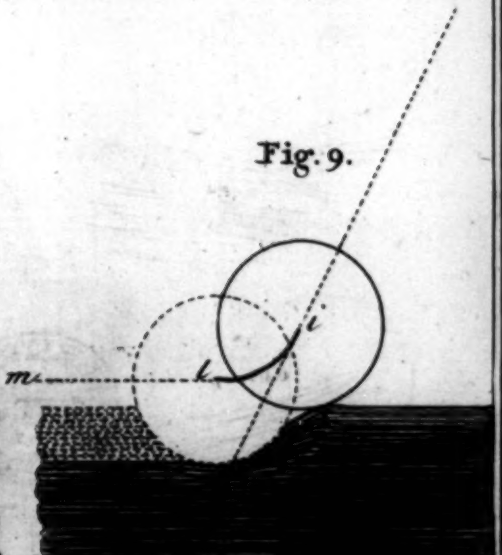

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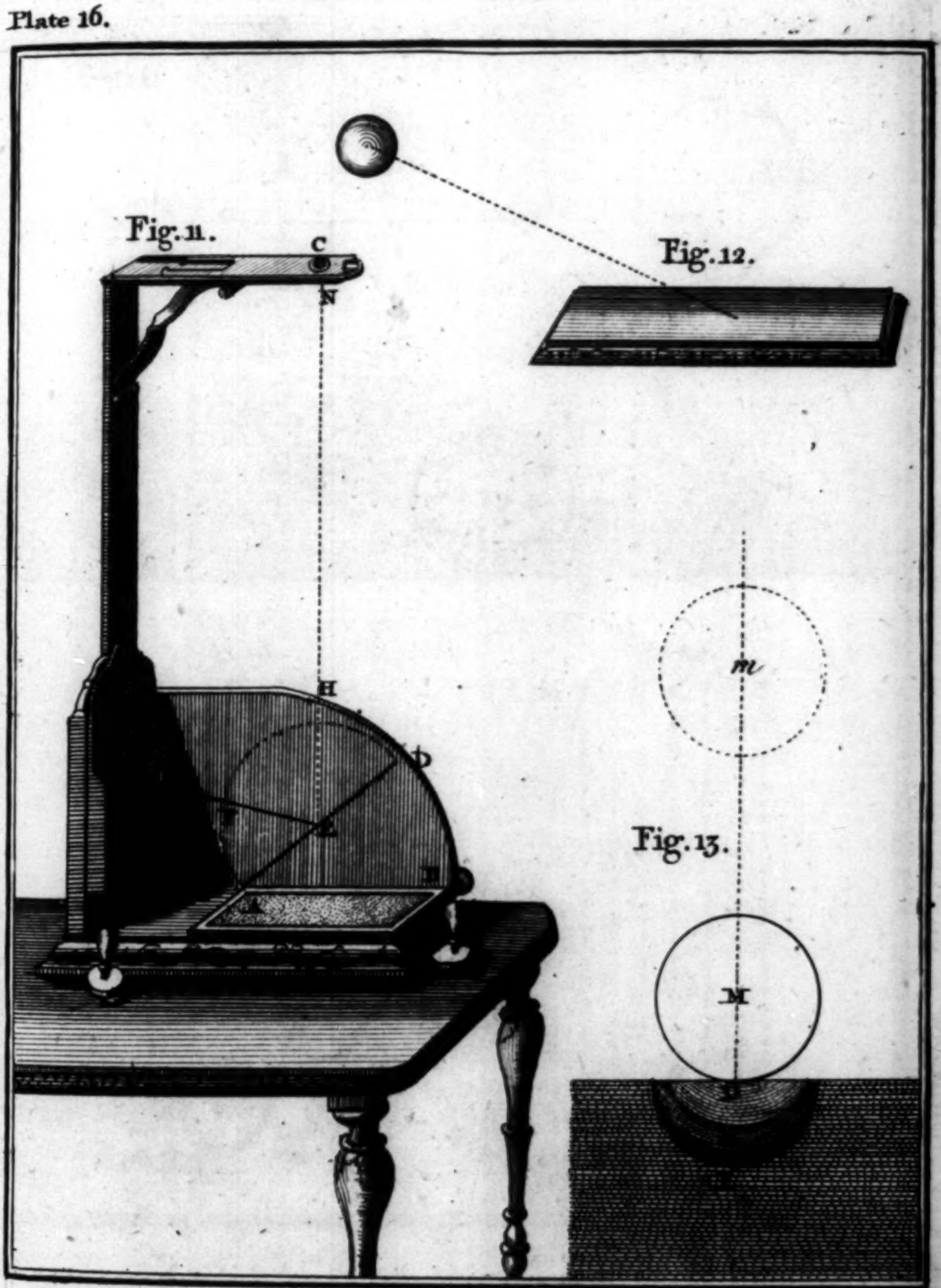

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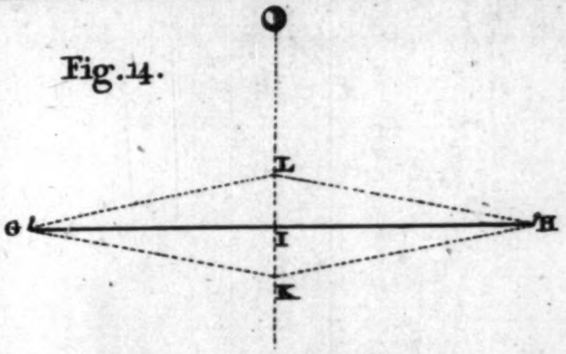
Plate 17.

Fig. 14.



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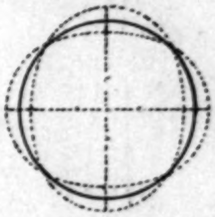

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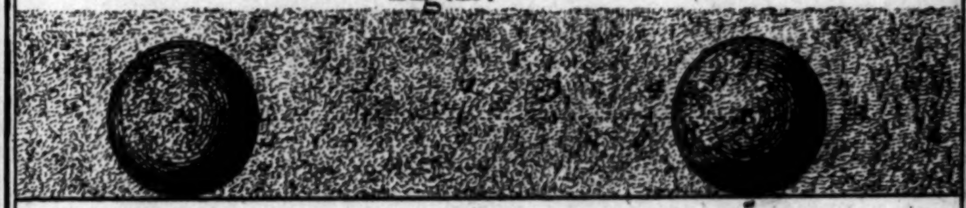

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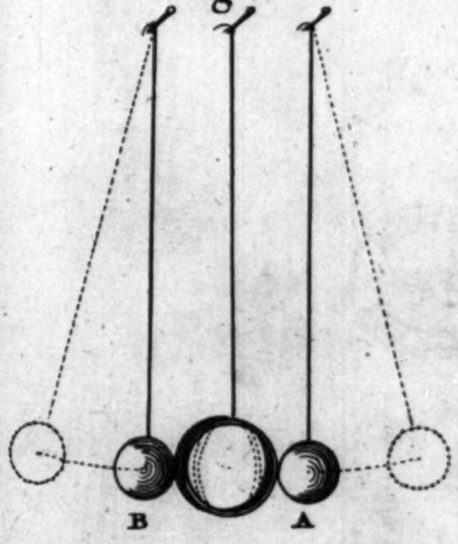

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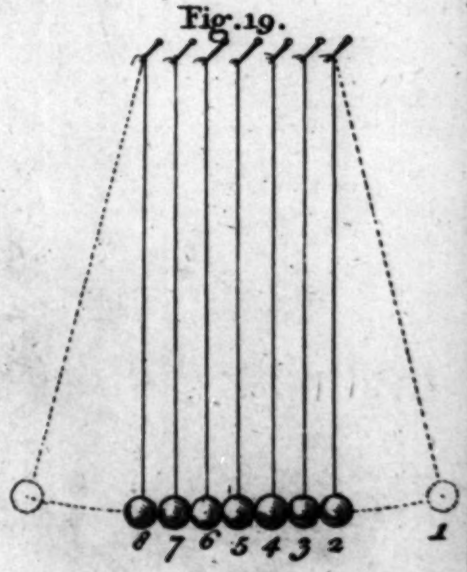

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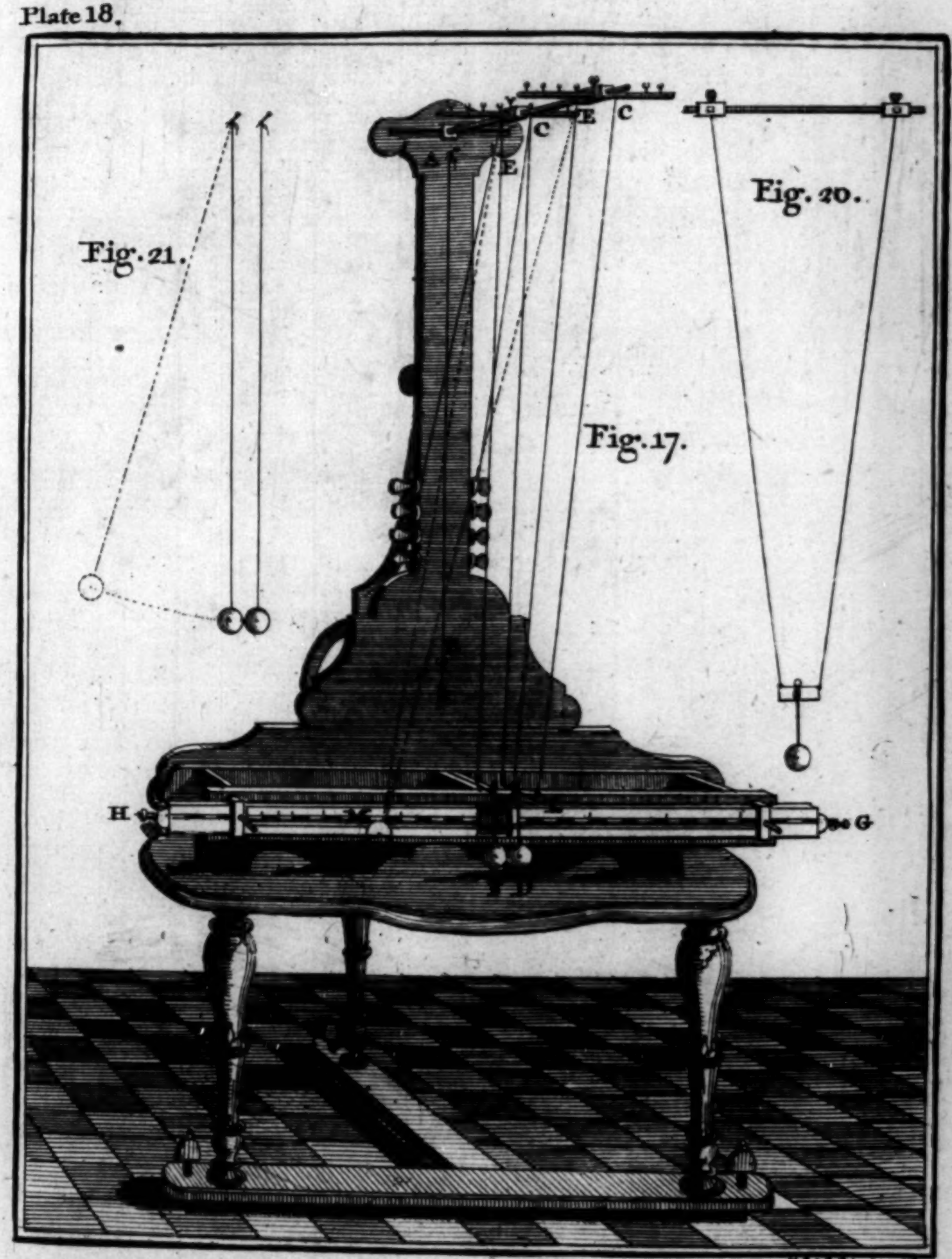

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